Sky and TELESCOPE

CHARLES A. FEDERER, JR., *Editor* HELEN S. FEDERER, *Managing Editor*

The Editors Note . . .

FOR an amateur astronomer, finding a new star must rank with the greatest of thrills. At least two regular readers of *Sky and Telescope* were fortunate in spotting Nova Puppis before they had heard of it from others, and they modestly wrote us to verify their "claims." See "Nova Notes" on page 5 for news of independent discoveries by professional astronomers, who also get up early, and look up at the sky when they do.

George D. Baird, well-known Oakland, Cal., amateur and long-standing member of the Eastbay Astronomical Society, wrote on November 10th:

"I do not wish to make any fictitious claim or be guilty of presumption, but I do wish to call attention to something unusual which I saw this morning. It is my habit to rise between 6:15 and 6:30 in the morning. I thought it was cloudy, but when I stepped out on my back porch, Orion, the Pleiades, and Sirius were simply magnificent. Then something to the left attracted my attention, and I stood at attention.

"There, about 25 degrees southeast of Sirius was an object I had never seen before, a brilliant star of about magnitude 1.5, ranking with Castor—brighter than an ordinary 2nd-magnitude star, yet not as bright as a 1st.

". . . I could not find any brilliant object on the charts, the brightest in that vicinity being in Puppis, probably 3rd magnitude, hardly more. . . . I will repeat the date—November 10th, just before sunrise, about 6:45."

And from Wm. J. Gallagher, of Cincinnati, Ohio, we received the following "prediction" of the discovery by Dr. Dawson:

"There is a new star. I think it is in Argo. (I have no maps.) I first saw it at 4:00 a.m., today (November 11th). It appeared to be about as bright as Regulus at that time, but it was as bright as Aldebaran by 6:00 a.m. . . . .

"I suppose it has been reported long before this, as it would show up better in the southern hemisphere."

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COVER: Nova Puppis 1942, photographed by Frank Bowie with an 8-inch telescope, 30-minute exposure, November 15th, at Harvard College Observatory. The diffraction ring is an optical effect and not a part of the star. Plates similar to this, but of shorter exposure, have been compared with those of the same region taken previously. No star is found in the nova's position, not even on plates taken at Bloemfontein with the 24-inch Bruce camera and a 3-hour exposure. The nova was originally fainter than the 17th magnitude!

BACK COVER: The spiral nebula N.G.C. 4565, in Coma Berenices, at R. A. $12^h\ 33.9^m$, $+26°\ 16'$. It is the largest edge-on spiral in the northern galactic hemisphere, and its total stellar magnitude is 10.7. Its oblate nucleus is conspicuous, as is also the band of absorbing matter. Numerous other galaxies are in the same field, some looking like plate defects. Mt. Wilson photograph, with the 60-inch telescope on March 6-7, 1910, exposure 5 hours.

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That Christmas Star

Visitors to the Buhl and Hayden Planetariums this month are told the story of Christmas stars, old and new, including Nova Puppis, latest possible re-enactment of the original Star of Bethlehem.

By Marian Lockwood

And, lo, the star, which they saw in the east, went before them, till it came and stood over where the young child was.

CHRISTMAS STAR? Christmas star this year, in 1942? Nonsense, you say. How could that be? The Christmas star, real or legendary, whichever it was, happened nearly 2,000 years ago!

But wait! On the 8-9th of November, 1942, there was discovered, blazing in the southern sky, a new star, a nova—it was brilliant, nearly of the 1st magnitude, and growing brighter. By the 11th, its magnitude was 0.5, equalling that of Procyon, 8th brightest star in all the sky!

In the constellation Puppis, not far from Zeta in this group, Bernhard H. Dawson, of the University Observatory, La Plata, Argentina, had discovered, in right ascension 8^h 9.5^m, declination $-35°$ $12'$, the star which may possibly be the Christmas star of 1942.

No one knows, as this is written, just how the star will develop. But already it takes its place among the three brightest novae in our galaxy this century. Only Nova Persei 1901, of maximum magnitude –0.8, and Nova Aquilae 1918, maximum magnitude –1.6, appeared brighter.

Throughout astronomical history the phenomenon of the nova—the "new" star—has baffled astronomers. Modern methods of study with powerful spectrographs and sensitive photographic emulsions have gone far toward explaining the physical changes in a star after it reaches greatest brilliance as a nova, usually tens of thousands of times brighter than its original luminosity, but the basic question of why the star bursts forth or "explodes" and where it gets the energy to do so is unanswered. But with each new nova our knowledge on this subject increases.

And now for the second time in recent years, a nova has appeared just before Christmas, bringing this year to a war-weary world a new star in the firmament—a new light in the sky of night. Even now, Nova Puppis is more brilliant than Nova Herculis, which appeared in 1934 a short time before the Christmas season and reached a maximum brightness of 1.7.

The appearance of this beautiful star brings forward very pertinently the belief of some astronomers that the star "which they saw in the east" may have been a nova of this same character. And the sight of this Christmas star—1942 edition—takes us back with even greater interest to the consideration of the Star of Bethlehem.

There are, generally speaking, three schools of thought concerning the Star of Bethlehem. Some people believe that it was supernatural. Others believe the whole story of the Christmas star, as well as the other details of the Christmas story, to be a legend, but a legend with great symbolic and religious value to the heart of man. Finally, there are those who think it may have been some kind of astronomical happening—a nova or a meteor, a comet or a conjunction of planets.

However, the Christmas star, whether it actually existed or not, has come to have indisputable validity in the minds of men, as the symbol of something high and noble, a "sign," if you will, of the divinity in man's own spirit.

The date of Jesus' birth is not known, and no definite and universally accepted date was chosen by the Christian Church until the end of the fourth century. However, January 6th, which was known as Epiphany, had been the most widely accepted date over a period of several centuries.

There was good reason for the choice of December 25th as Christmas. From the earliest times this date, which had been erroneously considered the winter solstice, had been celebrated as the birthday of the sun. We have the word of a Christian Syrian writer of those days, who says, "the reason the Fathers transferred the celebration from January 6th to December 25th was that it was the custom of the heathen to celebrate on the same December 25th the birthday of the sun, at which they lit lights in token of festivity and in these rites and festivities the Christians also took

Here is the first photograph of Nova Puppis taken on Mt. Wilson, and perhaps the first in the whole world. Anthony Wausnock, of the Monastery on Mt. Wilson, was really photographing the valley lights of Pasadena and Los Angeles on the first night of the dimout in those cities—the night of Sunday, November 8th. During the long exposure necessary to show the distant lights, the stars in the field formed trails, that of Canopus, second brightest star in the sky, showing on the right. The faint trails are those of Gamma in Vela and Zeta in Puppis. But Nova Puppis, itself, is caught as the bright trail in the upper left corner!

part. Accordingly, when the doctors of the Church perceived that the Christians had a liking for this festival, they resolved that the true Nativity should be commemorated on that day."

As there was no way of ascertaining the exact date of Jesus' birth, so there is no sure way of finding out the year of his birth. Most people take it for granted that Jesus was born in the year 1 A.D. However, because of our knowledge of early calendar discrepancies, and by referring to the chronology of certain known historic events, we can be sure that Jesus must have been born at least as early as 4 B.C., and possibly as early as 11 B.C. The first year mentioned is that of the death of King Herod.

It is worthwhile, then, to examine, in our search for the identity of the Christmas star, any bright heavenly object which was recorded in those years, and which can be at all well verified. Since the Wise Men had been long watching for a "sign" in the heavens as a warning of the coming of the Messiah, in fulfillment of their ancient prophecies, they certainly would not have accepted an ordinary astronomical object as a sign. They would have expected it to have unusual brilliance or beauty.

Some have suggested the planet Venus, at a time when it appeared as an evening star and at its greatest brilliance. Venus is without doubt one of the most beautiful objects in the sky—brighter at its brightest than anything else except the sun and the moon. It seems questionable, however, that men who had been accustomed to watching the sky for signs, and who therefore must have known its appearance well, could mistake an object as frequently seen as Venus for something unusual enough to serve as a sign from Heaven.

Anyone who has spent any time whatever under the night sky has recognized the occasional flights of meteors streaking across the starry sphere. Meteors are, for the most part, tiny particles of matter, billions of which collide with the atmosphere of the earth during every 24-hour period. Some move together in large companies, or swarms, around the sun in orbits not unlike those of the planets.

As these meteoric bits speed through the atmosphere at a rate of many miles per second, friction with the air occurs, heating meteor and air to incandescence. The observer sees a streak of light where the meteor has passed. Occasionally, one sees an exceptionally brilliant meteor which stands out like a beacon in the sky. Such meteors are called fireballs, and may leave luminous trains which persist in the sky for several minutes. Sometimes they explode with audible detonations.

It is possible, then, that the Star of Bethlehem may have been a very bright meteor, but it seems unlikely that anything as ephemeral as the passing of a meteor would have been taken by those watchers as a true sign. Fireballs, however, with their startling brilliance, and sometimes vivid display of colors, are awe-inspiring objects to behold.

Nova Puppis 1942. Compare the left-hand picture, taken November 12th, with the one on the right, taken about 1900 in Peru. The earlier photograph has a slightly smaller scale, but it is easy to ascertain that there is no star on it in exactly the nova's position.

Or the Christmas star may have been one of those beautiful and leisurely visitors from space which we call comets. A bright comet is one of the most spectacular sights visible to the eye of man. Many people remember with great interest the visit of Halley's comet in 1910, when it came so close to the earth that our planet actually passed through the nebulous tail. A comet's head is composed of more or less solid particles of meteoric material, but the tail, which increases in length and brilliance as the comet nears the sun, is tenuous in the extreme.

The Chinese, who have long been great astronomers, observed an especially bright comet in the year 4 B.C. If that one were of such brilliance that it could be seen in the daytime, as has been true of some, it would undoubtedly have attracted a great deal of attention. Through the centuries the appearance of comets has always been linked, in the popular mind, with the birth and death of kings, with the occurrence of natural catastrophes as well as those of man-made origin, and with the prophecy of future happenings.

We can imagine the Wise Men interpreting the peculiar shape of the comet, if that indeed *was* the Christmas star, as a divine finger pointing out the direction in which they should travel.

One of the most interesting suggestions was made at the beginning of the 17th century by the great astronomer, Johannes Kepler. In 1604, he observed the apparent coming together of three planets, Jupiter, Saturn, and Mars, the three forming a small but spectacular triangle in Pisces. These three planets move at very different speeds around the sun, Jupiter making the trip in about 12 years, Saturn in nearly 30, and Mars in less than two. Because of this disparity in speed, the three planets appear together only about every 100 years in this triangular formation, and approximately once in 800 years this occurs in the constellation of Pisces, as Kepler discovered. He also found that this "triple conjunction" occurred in the spring of the year 6 B.C., and also in Pisces.

For the Hebrews, the Fishes had long held special religious significance, and they would therefore be predisposed to consider any unusual astronomical object in that part of the zodiac as a sign.

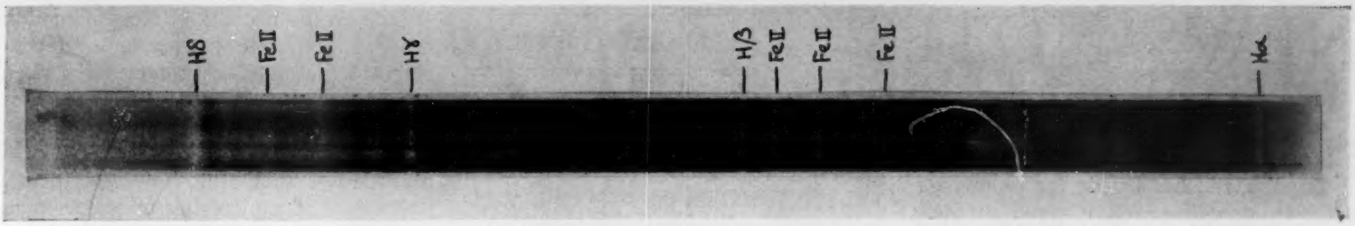
However that may be, it is without doubt true that the triple conjunction of Jupiter, Saturn, and Mars, in 6 B.C., must have attracted a great deal of attention. On the skies of our modern planetariums, with the stars and planets turned back to their positions of two millenia ago, the grouping is dramatically portrayed, and even those who have seen the phenomenon reproduced many times never fail to be fascinated by its repetition.

The objection has been made that this grouping of planets was not a star, and therefore could not have been the Star of Bethlehem, but to many persons any brilliant celestial object is a "star," and this was especially true in ancient times. And in this case, the three planets are very close together, so the designation of star might easily have been applied to them.

Astronomers, today, are in no position to solve the mystery of the Christmas star—no one can say with any certainty what it really was. But whatever it was, legendary, miraculous, or real, the Star lives in our hearts and minds, its clear and beautiful light a symbol of the hope for "Peace on earth toward men of good will."

69TH A.A.S. MEETING

Upon the invitation of Dr. O. J. Lee, director of the Dearborn Observatory, the American Astronomical Society will convene at Northwestern University, December 28-30th, for its 69th meeting. A provisional program includes sessions for papers, a conference for teachers, and probably a discussion on navigation or other timely subject.



A spectrum of Nova Puppis obtained by W. W. Morgan with the 40-inch Yerkes Observatory refractor on November 11th. It is a negative, so absorption lines show white and emission lines, dark. The strongest absorption lines are those of hydrogen, marked Hα, etc., and ionized iron, marked FeII. Alongside the absorption lines appear emission components, due to the shell of gas emitted by the star's outburst, that next to Hα being particularly noticeable. It is from a series of spectra similar to this one that the physical changes in the star can be determined. This spectrum is similar to Nova Herculis 1934, before it reached its greatest maximum.

NOVA NOTES

AT noon on November 10th, a cablegram was received at the Harvard astronomical clearinghouse reading: NOVA NEARLY FIRST MAGNITUDE 08095 RIGHT ASCENSION –3512 DECLINATION DAWSON and signed by Enrique Gaviola, director of the Argentine National Observatory at Cordoba, Argentina.

This brief message was the first official news of the discovery of Nova Puppis 1942 received at Harvard, although it turned out later that several independent discoveries had been made but not reported yet. As nearly as we can ascertain, Bernhard H. Dawson, of the University Observatory, La Plata, Argentina, and author of the article on Alpha Centauri in *Sky and Telescope* last month, made his discovery before anyone else, presumably on the night of November 8-9th.

The words "nearly first magnitude" told the story in a nutshell. And the next morning it turned out to be even brighter than they would seem to indicate. It was about 0.8, or brighter than Altair, 11th brightest star in the sky. This made it the third brightest nova this century!

Not since 1918 had such a brilliant new star appeared. Then Nova Aquilae appeared in the constellation of the Eagle, and reached –1.6, as bright as Sirius. And prior to that, in 1901, Nova Persei burst forth to equal Canopus for a while.

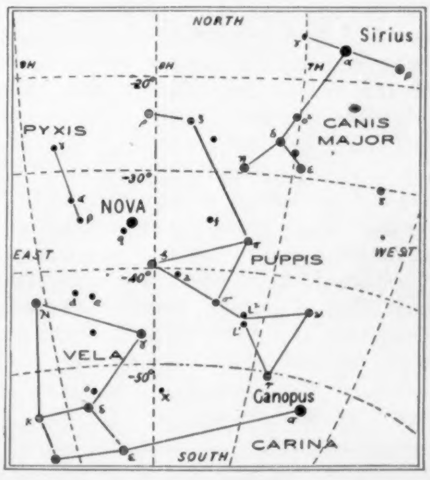
On the 12th, our latest nova had reached what is apparently its first maximum, if not its only one. It was then 0.5, equal to Procyon. The morning of Friday, the 13th, was cloudy, but on Saturday, Leon Campbell, A.A.V.S.O. recorder, estimated Nova Puppis to have faded to 1.1; on the 14th, it was 1.9, and on the morning of the 15th, it was only 2.4, indicating a rapid loss of light. How long it will remain visible to the naked eye, no one at this writing can say. It may also suddenly decide to increase its brightness once more, so amateurs are requested to forget their slumber, and rise in the small hours to keep track of the light fluctuations.

During November, the nova crossed the meridian, about 15 degrees high in the latitude of New York City, around 5:15 a.m. war time, but this time of crossing will get four minutes earlier each day.

Those who looked for the nova, in spite of its southerly declination, were surprised to find it well above the horizon and very conspicuous, in a region containing few bright stars. The stars in the Big Dog's tail made excellent comparisons, as did, in fact, the host of winter 1st-magnitude stars when the nova was at maximum, but as it fades, fainter and fainter stars must be used. Care should be taken to make allowances for the color (spectral type) of the comparison stars.

THE SPECTRUM

WE are indebted to the Yerkes Observatory for a copy of one of the very first spectra of the new nova taken in this country. In sending it, Dr. Otto Struve, director of Yerkes Observatory, wrote:



Watch the nova carefully, and compare its magnitude with the stars on this chart. Some, with spectral class, are: λ Vel, 1.93, K5; ζ Pup, 2.27, Od; π Pup, 2.44, K5; ρ Pup, 2.75, F5; ν Pup, 3.11, B8; α Pyx, 3.68, G5; q Pup, 4.42, A5; f Pup, 4.59, B8. The magnitude may increase at any time, as fluctuations often follow the first drop in brightness.

"The features of the spectrum are very broad and it is not possible to obtain more information from plates secured with high dispersion. The photograph does not show the region of the interstellar calcium lines, which indicate a very considerable distance and motion of expansion of the order of 1,000 kilometers per second."

Apparently, as in previous novae, a shell of gas is expanding around the nova.

INDEPENDENT DISCOVERIES

OUT Mt. Wilson way, Dr. Edison Pettit, a solar specialist, went out to get the morning paper from in front of his house Tuesday morning, November 10th, looked up, and spotted Nova Puppis! It was a simple matter for him to check the position with his 6-inch backyard telescope, and to *measure* its brightness with the photometer which happened to be attached to it. The nova was then about as bright as Rigel, which is of magnitude 0.34. The southern latitude of Pasadena gave Dr. Pettit a view at a considerably greater altitude than for more northerly observers, so the absorption of its light by the atmosphere would not be nearly as great.

And up in Michigan, on the morning of November 11th, Dr. A. D. Maxwell, of the University of Michigan Observatory, found the nova. Later in the week, when things seemed to be quieter, a cablegram came from Europe telling of the discovery of the nova by Finsler, of comet fame. The message had crossed ours to them.

Ferdinand Hartmann, of St. Albans, Long Island, picked up the nova independently on the morning of November 9th, while he was waiting for a bus. An amateur and A.A.V.S.O.er, Hartmann estimated its magnitude at 0.7.

In our editorial space, we have quoted parts of letters of discovery from two American amateurs. Undoubtedly, there have been other independent discoveries of which we have not been informed. But it does seem that all were antedated by the observation in Argentina, which—the nova being in the Southern Hemisphere—is just as it should be. Congratulations, Dr. Dawson!

NEWS NOTES

By Dorrit Hoffleit

MOON ILLUSION AGAIN

One of our readers, W. F. Henderson, of Chicago, Ill., has sent in the following letter (quoted in part), inspired by our note in the September number on Prof. Boring's investigations of the apparent size of the moon.

"Recently, when flying at an altitude of 4,000 feet, we crossed an area which included many lakes. A near-full moon was above us and, as I looked down, I could see the reflection of the moon intermittently in the water. Naturally, trees and houses looked small, but the moon's reflection looked huge, sometimes filling an entire lake. Yet I knew that actually the moon's reflection was the same size as the moon itself. Here we had the opportunity of comparing the moon's disk simultaneously in two settings—one high in the sky and the other adjacent to the landscape."

Mr. Henderson favors the time-honored explanation that one's judgment of the apparent size of the moon depends on a comparison with terrestrial objects. In view of Prof. Boring's rejection of this hypothesis, we wish that such observations as Mr. Henderson's might be made while the plane is looping the loop. The illusion might be quite different with the observer's head oriented in another than the normal position.

NEWS TAKES TIME

Last month we reported on the rediscovery of Comet Schwassmann-Wachmann by Miss L. Oterma, of Finland, who thought it was a new comet. Since then we have received word of her discovery way back in February of a really new comet. The cablegram that should have reached Harvard eight months ago was never received. We finally heard about the discovery through the much-delayed printed circular that came by "ordinary" mail from Copenhagen. The new comet was only of 15th magnitude when Miss Oterma found it on February 12th.

HANS ADAMSON FOUND

Col. Hans Christian Adamson, first editor and originator of The SKY, was among the men reported missing with Capt. Eddie Rickenbacker in the Pacific in October. Twenty-five days later, when they were found, Col. Adamson was in good condition. He has served with the press relations department of the Army Air Corps since last January, prior to which he was head of radio and press relations for the American Museum of Natural History.

Among his many other activities, Col. Adamson brought into existence the Hayden Planetarium *Bulletin*, a monthly which had a large sale during the New York planetarium's first year. In November, 1936, he enlarged the *Bulletin* to The SKY, and set the style for a popular astronomical journal illustrated generously with large halftones of celestial objects. Col. Adamson remained editor until February, 1938, when he was succeeded by Dr. Clyde Fisher.

HOW ROUND IS THE EARTH'S EQUATOR?

Our elementary textbooks tell us that the figure of the earth is an oblate spheroid, the equatorial cross-section being a circle, and any section perpendicular to the equator an ellipse. But is the equatorial cross-section really a circle? Apparently a great variety of studies have been made to ascertain how round the earth really is. This was the subject of a geophysical discussion of the Royal Astronomical Society recently, on which R. Stonely reports in *Nature*.

Observations of the moon, triangulation of the earth's surface, measurements of gravity (by deflection of the plumb line from its expected position) and observations for precession and nutation have been utilized. The various methods all agreed in giving a value of the eccentricity of about 1/296 (= .003). Readers of *Sky and Telescope* may remember the diagram in the September issue illustrating the smallness of the difference in shape between Mercury's orbit (eccentricity .206) and a circle. Yet for our equator an eccentricity only 1/100 that of Mercury's orbit has been reliably determined.

TWO CABLEGRAMS!

November 10th was a very busy day at Harvard College Observatory. For telegrams always provide excitement and hustling about to confirm discoveries. And two cablegrams came that day, the first announcing another comet found by Miss Oterma, and the other a brilliant nova discovered by Dawson at La Plata.

Although the weather was extremely bad that evening, Leon Campbell, recorder of the A.A.V.S.O., observed the nova at 5:30 the next morning, and estimated its magnitude at 0.8, about as bright as Betelgeuse.

CORRECTION

In the June issue, page 11, F. J. Skjellerup was unfortunately referred to as a "Finnish astronomer." We appreciate Mr. Skjellerup's pointing out to us that he is a British subject born and living in Australia; his father was originally a Dane and his mother an Englishwoman.

Late on the evening of November 9th, Dr. F. L. Whipple was examining recent Harvard plates. The last one he looked at had a fuzzy speck on it. There was no other plate at hand exposed on the same region the same day the plate was taken, November 5th. Now and then it happens that a plate has a defect on it. Dr. Whipple decided the final checkup on this little speck could wait until morning, but then the news came that the speck was a comet, already found by Miss Oterma. She had found it on November 6th, when it was of the 13th magnitude. We have already mentioned her previous comet discoveries this year.

Dr. Whipple, however, computed the comet's orbit as soon as enough observations became available, and his calculations showed that this is not a new comet either. The orbital elements prove that it is the same as one that Stephan found way back in 1867 (Comet 1867 I). It moves around the sun in a period of about 40 years.

A TERCENTENARY

The tercentenary of the race of computing machines deserves mention here, for they are invaluable servants alike to astronomy and to the war effort. The first calculating machine was invented by Pascal in 1642. The Royal Astronomical Society is modestly celebrating the event in London, together with members of the Fighting French and British men of science.

ANOTHER ORIGIN FOR THE SOLAR SYSTEM

Would that we could observe the birth of a planetary system! For no theory on the origin of our solar system has yet received the unanimous support of astronomers.

A new version of the close-encounter theory has recently been published by A. C. Banerji in the *Proceedings* of the National Institute of Sciences of India. He supposes that the material of the sun and the planets was once part of a Cepheid variable star having a mass about nine times that of our sun. The Cepheid variable, a pulsating star, was passed at a moderate distance—say 200 astronomical units—by another star of about the same heavy mass. This encounter produced unstable tides in the Cepheid, with the consequence that a great deal of material was ejected from it.

Banerji finds that the ejected material could form a solar system having about two fifths of the energy of the original parent Cepheid. We quote him: "The encounter need not be very close, nor need the intruding star have an inordinately large velocity, to give the requisite angular momentum to the Sun and its planets and enough energy to the Solar System to escape from the parent Cepheid."

RELATIVITY . . .

and Its Astronomical Implications

By Philipp Frank, *Harvard University*

PART III

7.* The primary Doppler effect and starlight

IN all astronomy texts, elementary and advanced, the importance of the Doppler shift in stellar spectra is discussed in detail, for it is upon this phenomenon that much of our information regarding celestial bodies depends. However, the law of optics describing the Doppler effect has sometimes been stated in a vague way which makes the understanding of its relation to the Einstein theory rather hard. We shall, therefore, review the fundamental statement of the Doppler effect, but suggest to our readers that they also review its explanation in their respectively favorite astronomy texts.

The traditional statement usually runs: If a star which emits light of a frequency of n oscillations per second is approaching our earth with a radial velocity v, the light from the star seems to have a frequency $n' = n\ (1+v/c)$ for an observer on the earth, where c is the velocity of light in a vacuum. Since this new frequency, n', is obviously greater than n, the color of the light seems to be shifted toward the violet end of the spectrum, as violet has the greatest frequency of visible light. But this statement might give the impression that n is the "real frequency" of the light, and that n' is only an "apparent frequency," the latter a kind of subjective impression produced in the observer's mind by the motion of the star toward the earth.

Restating the facts, we should say: Every receiving instrument at rest relative to the star receives n impulses per second, but if the receiving instrument is approaching the star (or the star approaching the instrument) with the radial velocity v, the instrument receives n' impulses per second. Both are equally objective facts which have nothing to do with the subjective impressions of an "observer."

The ratio of n to n' is usually made photographically by comparing the positions of lines on spectra from laboratory sources with those from the stars. The laboratory sources are at rest relative to the receiving instrument—the photographic plate—while the star is in motion. Of course, the "motion" of the star may be partly due to a motion of the earth, as, for instance, the result of the earth's revolution around the sun.

It is more convenient to state the Doppler formula in terms of wave length than in terms of frequency. The general relation is given by $n = c/\lambda$, where λ is the wave length. If λ' is the wave length corresponding to n', then the Doppler formula becomes

$$\frac{\lambda - \lambda'}{\lambda'} = \frac{v}{c}\,.$$

Usually, the shift is very small, and λ can replace λ' in the denominator; also, let us call the shift $\Delta\lambda$—it is equal to $\lambda'-\lambda$. The final formula then becomes

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}\,.$$

In this formula, an increase in wave length (red shift) corresponds to a positive velocity—indicating increasing distance (recession) of the star.

Suppose, for example, we measure the shift of the D (yellow) lines in a star's spectrum and it amounts to 1/10 of an angstrom. One angstrom is 10^{-8} centimeters. The wave lengths of the D lines are near 5900 angstroms, or 5.9×10^{-5} cm. The speed of light, c, is about 3×10^{10} cm./sec. Therefore, as the D lines in a star's spectrum experience a shift of $\Delta\lambda = 0.1$ A., we obtain $v = 5 \times 10^5$ cm./sec. But 10^5 centimeters is one kilometer, so five kilometers per second, or about three miles per second, is the relative motion along the line of sight.

It is important to understand that the shift, $\Delta\lambda$, is one and the same in the

* The preceding section should have been number 6.

A Summary of the First and Second Installments

NEWTON'S laws of motion are correctly considered in terms of acceleration and mass. Lack of acceleration is shown by constant speed in a constant direction. Newton's basic principle is that acceleration is inversely proportional to mass, with "force" a proportionality factor: as the mass increases, the acceleration becomes smaller in a constant field of force.

If the force is zero or the mass infinite, the acceleration is zero. This means, the motion is rectilinear with constant speed. The geometrical form of the orbit is independent of the value of the mass (provided the mass is sufficiently great).

This *geometrical* path of an infinite mass is a straight line and of uniform speed only if referred to a certain system of reference, which is called the *inertial* system. This system is in a first approximation the system of the fixed stars. In some other system, the geometrical path may appear curved, or it may appear that the mass has an acceleration. (This thought is directly applied to gravity by Einstein, but not by Newton.)

But when "forces" act on a mass which is not infinite, a dynamical component is added to its geometrical motion. In an inertial system, this is easily distinguished because it is either curved or non-uniform, whereas the geometrical component is neither. But in any other system of reference, the distinguishing becomes more difficult, and must be done by varying the mass, to see how its acceleration changes. Increasing the mass to infinity will make its motion purely geometrical.

Galileo had looked for the dynamical component in falling bodies, by changing their masses, but he obtained the peculiar result that the acceleration of a falling body is 32 feet per second each second regardless of its mass. This did not fit well with the ideas of the relation of mass and acceleration, for if a *constant* force were acting on the masses, the heavy ones should be accelerated more slowly, and take longer to fall from a given height.

Newton accounted for this apparent disagreement by assuming that the force of gravity must be variable—that it must increase with the mass, and so massive bodies, pulled down by a greater force, fell as fast as light ones. Then the disagreement disappeared in "equating the equations."

Einstein regarded this "inseparability" of the inertial and dynamical components as the essential feature of the gravitational motion.

AN alternate explanation for the observed phenomena of "gravity" is furnished by Einstein's principle of equivalence. He proposes that a homogeneous field of gravitation is equivalent to acceleration on the part of the reference system itself with respect to another system which is an inertial system. No concept of force is involved in this new kind of gravitation—it is merely the result of the geometry of motion and matter. Einstein retains the word *gravitation*, but it no longer has special and unexplainable significance.

If true, Einstein's new principle should apply to light waves as well as to more tangible matter. The resultant deflection of a beam of light in a gravitational field may be calculated, but it proves to be exceedingly small in the case of phenomena on the surface of the earth. Applied to starlight passing the sun, it is thousands of times larger—specifically, 0.87 seconds of arc for a star appearing just at the sun's edge.

However, the consequences of the principle of equivalence are tied in with the concept of the curvature of space, which is again insignificant in terrestrial cases. But for starlight passing the sun, the "straight line" path is actually curved by another 0''.87, so the entire Einstein "bending of light" is expected to be 1¾ seconds of arc, a sizable and observable quantity.

Confirmation of the complete theory of Einstein resulting from his equivalence principle came with the total eclipse of the sun of May 29, 1919, at which astronomers obtained an observed shift of the position of a star close to the sun amounting to 1''.64, close to the predicted value of 1''.75. Lick Observatory astronomers obtained further and conclusive proof in 1922.

whole receiving system, if this system is rigidly connected with the earth. If we denote, again (see previous installments), the system of reference connected with the earth by E, we can say: The frequency of the light from a certain star relative to the system E has a definite set of values which are independent of the place in E where the measurement is performed. Or still more concisely: If n is the frequency of light from a star relative to a system in which the star is at rest, the frequency of the same star relative to E (which has the velocity v) is $n\ (1+v/c)$, and is independent of the co-ordinates of the points in E.

8. The secondary Doppler effect

WE consider now the case of a star which emits light and is at rest relative to the inertial system J. The receiving system, our earth, according to the alternative explanation of gravity, may be uniformly accelerated with respect to J, as we already visualized in our previous discussions. The acceleration of E may be a, and its direction may be parallel to the light ray coming from the star.

Consider particularly two points P and Q in the system E. The light passes through P and arrives later at Q, having traveled the distance L between them. Assume, for purposes of simplification, that the system E has just zero velocity relative to the star when the light ray passes P. Since the speed of light is c, the light ray arrives at Q after an interval of $t = L/c$.

But by the time the light ray reaches Q, the velocity of E relative to J has increased from zero to at or aL/c, since the acceleration is uniform. Now the number of vibrations per second received by a receiving system at P may be n; but when the light passes Q the receiving system there has the velocity aL/c, since it is part of E. Therefore at Q, according to the Doppler principle, n' vibrations per second are received. From the formula in the preceding section we obtain:

$$n' = n\ (1+v/c) = n\ (1-aL/c^2).$$

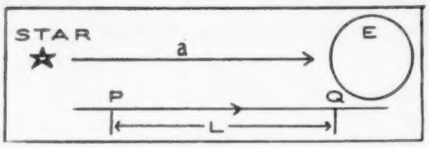
If we express this relation again in terms of wave length, replacing n by c/λ, we obtain:

$$\frac{\Delta\lambda}{\lambda} = \frac{aL}{c^2}.$$

We notice that the wave length of starlight received and recorded is different at different distances, L, from P; that is, the wave length is different at various points in the system E. This is called the secondary Doppler effect.

While the primary effect comes from the *velocity* of our earth relative to the star, and has the same value at all points in the system E, the secondary effect comes from the *acceleration* of E, and has a value changing from point to point of E. The farther we go in the direction of acceleration, the greater is the increase in the frequency. If we proceed inversely to the acceleration, the frequency decreases, and there is a "red shift" of the spectral lines.

If we were to consider the relative velocity of E and a star as the result of such an acceleration a, then, starting from rest, the velocity w at a distance L is given by the well-known formula for space-passed-over: $L = 1/2\ at^2$. But $w = at$, so $aL = 1/2\ w^2$. Substituting this in the secondary Doppler effect formula, we obtain: $\Delta\lambda/\lambda = w^2/c^2$. Suppose the value of w is about 20 km./sec., which is about the average observed for stars. Then $\Delta\lambda$ turns out to be about 1/10,000 angstrom for yellow light, which is beyond the limits of any possible observation.



The secondary Doppler effect has to do with the acceleration of system E relative to the star (J). P and Q are points in E, the light arriving first at P, and later at Q.

Indeed, the secondary Doppler effect has never been observed directly, but its existence is the starting point of Einstein's theory of the effect of gravity upon the frequency of light.

9. The secondary Doppler shift and the Einstein effect

CHRISTIAN Doppler advanced his principle in 1842, when he was professor at the University of Prague. Seventy years later, in 1912, Albert Einstein held the same position in the same university and advanced the generalization of Doppler's principle which led him to the prediction of the effect of gravity upon the frequency of light. This has since been known as the Einstein effect.

As discussed in the preceding section, if we make investigations in the system E, which has an acceleration a relative to J, we notice that light traveling in the direction of the acceleration has different frequencies, n', at different points of our system. By observing these differences from two points at a distance L apart, we can compute the acceleration of our system.

But according to Einstein's principle of equivalence, the effect of such an acceleration on any optical phenomenon in our system can never be separated from the effect of a field of "gravity." The same effect which is produced by the acceleration a can be produced also by a field of gravity. The forces in this field are directed *inversely* to the acceleration, and their intensity is such that they produce just the acceleration a of any mass moving in the field. This means in our case: The shift of the spectral lines which we ascribed to the secondary Doppler effect can also be ascribed to a force of gravity which points from Q to P, or, in other words, which is an attraction toward the star.

The potential energy difference from Q to P, owing to the field of gravity in which they are situated, is $\Delta\phi = aL$. Since, according to the principle of equivalence, the shift of wave length, $\Delta\lambda$, produced by this field of gravity must be exactly the same as the shift produced by the secondary Doppler effect, we have only to replace aL in the formula by $\Delta\phi$. The shift of wave length by gravity, the so-called Einstein effect, is then given by the formula:

$$\Delta\lambda/\lambda = \Delta\phi/c^2.$$

All this means, then, that if light travels through a potential difference $\Delta\phi$, in a field of gravity, then a shift in the spectral lines should be observed amounting to $\lambda\Delta\phi/c^2$. When a light ray is emitted from the surface of the sun or of a star and travels toward the earth, the potential of gravity is always increasing. When the light approaches the domain of gravity of the earth, the potential begins to drop, but since the gravity of the sun and stars is much greater than that of the earth, we can neglect the latter, and consider $\Delta\phi$ the potential difference between the star and empty space. Therefore $\Delta\phi$ is always positive, and $\Delta\lambda$ is negative—toward the red.

To provide an idea of the order of magnitude of this Einstein effect, we may substitute for $\Delta\phi$ its value in the case of the sun. According to Newtonian gravitation, it is kM/R, where M is the mass of the sun and R, its radius. The new Einstein formula then becomes:

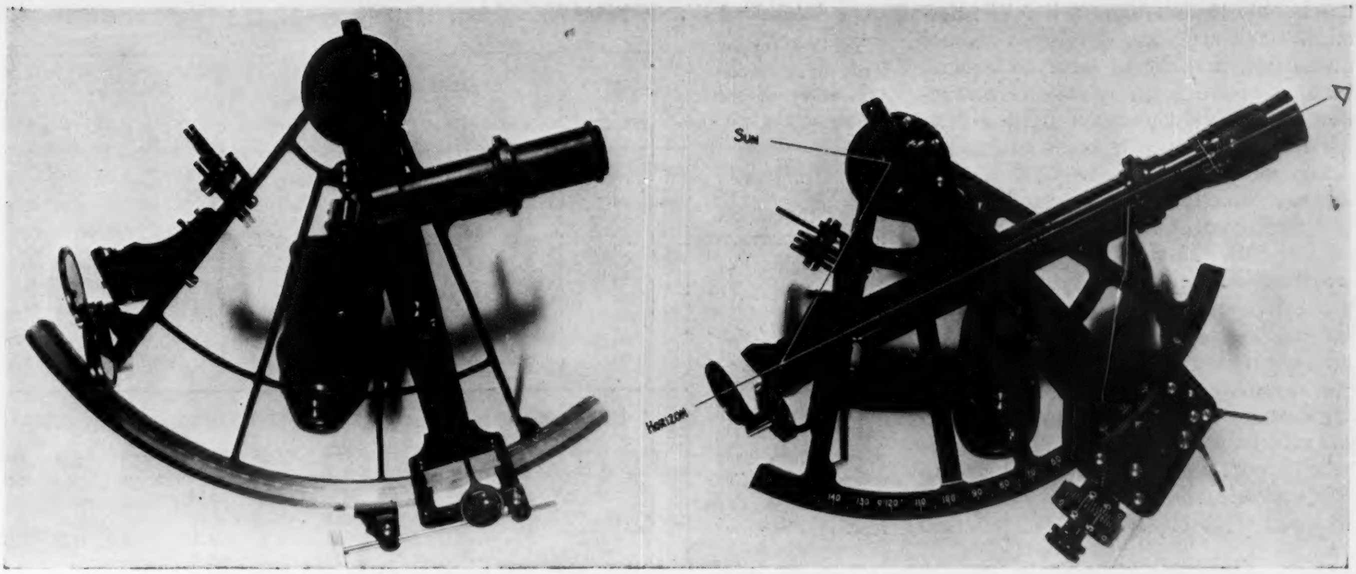
$$\frac{\Delta\lambda}{\lambda} = \frac{kM}{c^2R}.$$

(Notice the similarity of this formula to that for the deflection of starlight past the sun, given in Part II.)

Using the D lines of sodium again, and other proper values for the sun, we obtain a value for $\Delta\lambda$ of about 1/100 angstrom. This is still very difficult to observe, but for some stars, such as the companion of Sirius, we can obtain much greater values than for the sun. The companion of Sirius has a mass slightly less than the sun's, but its radius is only about 24,000 miles, or about 1/30 the sun's. Therefore, the Einstein effect should be observable in the spectrum of the companion of Sirius as a red shift 30 times as great as for the sun, or 3/10 of an angstrom.

Were it not for the extreme brilliance of Sirius itself, this shift in its companion's spectral lines might be easily observed, but in actual practice, some scattered light from Sirius always appears in the slit of the spectrograph. Nevertheless, W. S. Adams, using the

(Continued on page 19)



Figs. 1 and 2. A standard vernier-type sextant (left); and a micrometer endless tangent screw sextant (right).

THE SEXTANT

By T. O. Brandon, W. R. Bailey, and J. E. Willis

United States Naval Observatory *

THE sextant is a portable instrument used in measuring the angular distance between two objects. As a navigational instrument, it is used chiefly to measure the arc on the sky between a celestial body and the horizon. When two or more observations of this kind are made, the latitude and longitude of the vessel may be determined, as outlined in Dr. Watson's article, "Elements of Celestial Navigation," in the September issue of this magazine.

History. The astrolabe, an instrument for determining altitude, was first known in its primitive form to the Greeks and Arabs about 240 B.C. The early astrolabe, especially the form used at sea, had a simple sighting bar, and a circular arc, and was suspended from the thumb in the same manner as the plumb bob. This device was used exclusively until the year 1594, when variations of the astrolabe were introduced. In 1676, the cross-staff superseded the astrolabe for measuring an altitude from the sea horizon. The cross-staff was also used for other purposes, as for measuring the angle between two points along the horizon. However, it required the observer to sight simultaneously in two directions; although superior to the astrolabe, it was still very inaccurate.

The cross-staff remained in use until in 1730, Thomas Godfrey, a glazier of Philadelphia, and Capt. John Hadley, of the British Navy, independently invented the octant. With the new instrument, the directly observed object (usually the horizon) is made to coincide as closely as possible on the half-silvered mirror with the reflected-observed object, the principle still in use in the sextant today.

But the octant was only an eighth part of a circle, as its name implies. In the year 1757, Capt. Campbell introduced the 60-degree arc (sextant) which extended the 90-degree range of the octant to about 120 degrees, thus initiating the modern marine sextant.

Types of Sextants. A standard type of the marine sextant is equipped with a vernier for reading the fractional part of the equal divisions of the altitude arc, as shown in Figure 1. Other types use a micrometer screw which remains tangent to the altitude arc when reading the fractional parts of degrees, as indicated on the altitude arc in Figure 2.

With these types of marine sextants, the altitude of a star may be observed from a ship, using the sea horizon, with an accuracy of the order of ½ minute of arc, which corresponds to about half a mile in determining the ship's position.

To use the sextant on land or in the air, an artificial horizon is usually necessary. The first effective artificial horizon consisted of a tray of mercury, the surface of which maintained a horizontal plane and at the same time provided a high reflecting surface.

Some sextants provide for observation of the horizon when that line of reference is available and are also equipped with a bubble device for use in hazy or inclement weather; they are similar to the first model of bubble-type sextant shown in Figure 3. Other bubble sextants have averaging devices which indicate the average setting over an interval of time or which assist the observer in estimating the average of a number of settings. Integrating devices are used in certain bubble sextants of foreign design.

The bubble sextant, utilizing a liquid pendulum device in lieu of the horizon, is used by apparently sighting through

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Thirty Steps for a Moon

Pale precious puppet, go follow him again–
The Sun, your master, through his broad domain,
And far behind, tied to his golden string
Begin again thy jerky wandering;
Gesture more feebly, grow less luminous the while
Like wan Elaine, with half-rotunded smile;
Grow faint, feign death, then falter in the skies,
Like pale Ophelia, sink before his eyes –
And then he'll turn, and look, and gild thy horn
And men will say below, "New moon is born."

PHYLLIS FREDERICK

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* The views expressed herein are those of the authors only, and do not necessarily represent the views of the Navy Department.

the bubble to determine a line of reference. Such a device, developed for use in the air, may be in error by several minutes of arc in an average of a number of observations taken from a fast-moving airplane. Figure 4 shows an octant which is similar in principle and use to the modern bubble sextant.

A radio sextant was developed in 1935 for use with the sun in foggy or murky weather. A parabolic mirror, having a photoelectric cell at its focus, was pointed in the direction of the greatest intensity of light and heat in the sky. It was moved to and fro and around until a galvanometer, connected in series with the cell, indicated a maximum of radiant energy received. It was then pointing to the invisible sun. The bulky batteries required were objectionable in practical use.

Various pendulum sextants have been proposed and developed, each containing a pendulum device for use in determining a reference line. One proposed pendulum sextant contains a buzzer system which sounds off when the instrument is not being held in an approximately level position.

A British pocket sextant, about three inches in diameter and weighing less than a pound, may be useful to the navigator as added emergency equipment for boat use. It can be used with or without a small telescope, is compact, and approaches the accuracy of the standard marine sextant.

Most of the latest developments in the sextant field deal with variations of the averaging sextants. Some devices do not use a telescope; but all are provided with an artificial reference line of one design or another.

The Care of Sextants. The U. S. Naval Observatory is the designated inspecting, overhauling, and issuing point for sextants in the Naval Service. The first operation in overhauling a sextant is the disassembly. Each disassembled part is inspected and such repairs as are found to be necessary are effected by craftsmen having a thorough knowledge of these instruments. The centers which form an axle for the index arm are straightened and lapped in, to make a true fit both on the shoulder and taper.

The lacquer and paint are removed from the instrument and all parts, including the screws, are refinished. If regraduation is necessary, the worn graduations are machined off and the silver is grained with a fine grade of charcoal and oil. When the inlaid silver on the arc or vernier becomes too thin for regraduation, it is removed and a new strip of sterling silver is inlaid. It is then machined flat and grained smooth as before. After new graduations are made by a dividing engine, new figures are engraved. Figures and graduations are filled with a hard, black, resinous wax.

After being resilvered, the mirrors are all tested for parallelism and adjusted after having been assembled in the instrument. The sextant telescopes are refinished and checked optically before assembly. The sextant is then mounted in a collimator and tested for errors in

TABLES I-IV. ORDINARY CORRECTIONS TO SEXTANT ALTITUDE

Table I (upper left). For nonverticality of the plane of the arc.

Table II (upper right). For dip of the visible horizon for various heights of eye.

Table III (middle). For refraction of light passing through the earth's atmosphere. (Low level temperature, 10° C., barometer reading, 750 mm.)

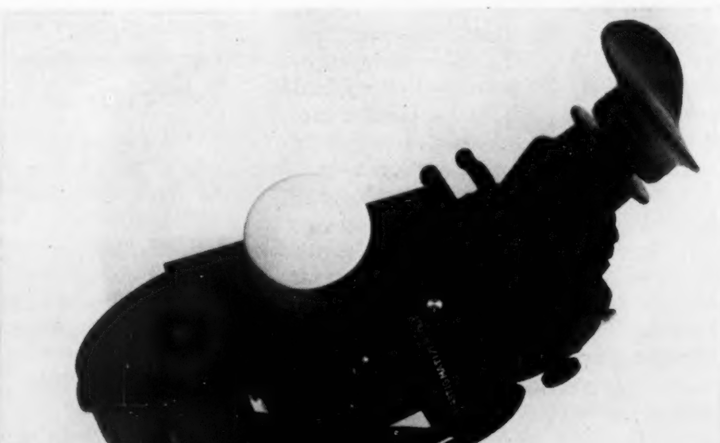
Table IV (bottom). To be applied to observed altitude of the sun's lower limb, for parallax and semidiameter of the sun.

ALTITUDE READING	CROSS-TILT 0°	2°	4°
0°	0′.0	0′.0	0′.0
10	0.0	-0.4	-1.5
20	0.0	-0.8	-3.0
30	0.0	-1.2	-4.8
40	0.0	-1.8	-7.0
50	0.0	-2.5	-10.0
60	0.0	-3.6	-14.5
70	0.0	-5.7	-22.8
80	0.0	-11.8	-45.8
90	0.0	-120.0	-240.0

HEIGHT	
0 Feet	0′.0
10	-3.1
20	-4.4
30	-5.4
40	-6.2
50	-7.0
100	-9.8
200	-13.9
500	-21.9
1000	-31.0
2000	-43.8
3000	-53.7
4000	-62.0

HEIGHT IN FEET ABOVE SEA LEVEL	OBSERVED ALTITUDE 5°	10°	15°	20°	30°	45°	60°
0	-9′.7	-5′.2	-3′.5	-2′.6	-1′.6	-1′.0	-0′.6
10,000	-6.9	-3.7	-2.5	-1.9	-1.2	-0.7	-0.4
20,000	-5.0	-2.7	-1.8	-1.3	-0.8	-0.5	-0.3
30,000	-3.4	-1.8	-1.2	-0.9	-0.6	-0.3	-0.2
40,000	-2.2	-1.2	-0.8	-0.6	-0.4	-0.2	-0.1

OBSERVED ALTITUDE	JAN. 1	APRIL 1	JULY 1	OCT. 1
10°	16′.4	16′.2	15′.9	16′.2
30	16.4	16.2	15.9	16.1
60	16.4	16.1	15.8	16.1
90	16.3	16.0	15.8	16.0



Figs. 3 and 4. An early bubble-type sextant (left); and a bubble octant (right).

eccentricity. Should an eccentricity error exceed the tolerance allowed, it is corrected by adjusting the axle mounting until it comes within the specified tolerance. A certificate of inspection is furnished with each sextant, showing the eccentricity corrections to be applied to the readings of the instrument in use.

Corrections. In order to determine the true altitude (h_o), which is complementary to the arc of the surface of the earth between the observer and the substellar point, it is necessary to apply to the altitude read on the sextant (h_s), the following corrections:

1. *Index* correction, obtained from the eccentricity-error chart furnished with each instrument, or from settings on the horizon or on stars of known angular separation.

2. Correction for *cross-tilt* of the plane of the instrument, illustrated in Table I.

3. *Dip* of the horizon if the sea horizon, or cloud horizon of known elevation, is used, illustrated in Table II.

4. *Refraction* of the light rays in passing through the earth's atmosphere, illustrated in Table III.

5. *Parallax* correction, if the object is not a star. This is due to the displacement across the line of sight of the observer relative to the center of the earth, and is of the order of 0′.1 for the sun and 50′ for the moon. It varies with altitude, and with distance of the object from the earth.

6. *Semidiameter*, if the limb (apparent edge) of the object is used instead of its center. Corrections 5 and 6 are illustrated together in Table IV.

7. The *personal* systematic correction for each observer, as determined by analyzing observations of known altitudes.

The preceding corrections are sufficient unless the observer is in rapid motion. On fast-moving aircraft, additional corrections may be needed if a bubble or pendulum takes the place of the sea or cloud horizon.

8. *Deflection* of the observer's plumb line because of the "Coriolis acceleration," resulting from the rotation of the earth, if the airplane is operated along a great circle of the earth's surface (Table V). This is the same deflection which is involved in the motion of air currents, ocean currents, and free projectiles of all kinds.

9. In the case of a bubble sextant, the liquid in the bubble chamber is free to become level and the chamber is forced to move with the traveling plane. Lag of the liquid undergoing accelerations causes undetermined errors which must be averaged out.

10. In the case of a pendulum sextant, the bob of the pendulum is free to swing, while the upper end is forced to move with the plane. Lag of the pendulum under acceleration is characteristic.

11. The correction for the deflection of the observer's plumb line, if the airplane's course is made to curve off a definite amount from the great circle, is indicated in Table VI. If an airplane is guided by a gyro device, with axis horizontal and not controlled to a rhumb line, imperfect balance and frictional forces cause the plane to move in a path whose curvature must be found by trial. Such curvatures are of the order of several 10ths of a degree per minute of time.

12. If the course of the plane is forced to be a rhumb line (line of constant azimuth), departure from the great-circle motion, at high speed and especially at high latitudes, will cause a deflection of the zenith perpendicular to the direction of motion. This will be of the order of minutes of arc, for which corrections may be applied as illustrated in Table VII.

The difference between the observed altitude (h_o) and the computed altitude (h_c) gives the distance on the earth's surface from an assumed point to a line of position. The observer's true position is at the intersecting point of two or more lines of position. Further data to determine the computed altitude, and methods to calculate the longitude and latitude, were given in Dr. Watson's article, previously mentioned.

TABLES V-VII. ADDITIONAL CORRECTIONS FOR BUBBLE OR PENDULUM SEXTANTS AND OCTANTS

Table V (upper). For deflection of the plumb-line zenith when the observer travels along a great circle of the earth's surface. (The true zenith is to the right of the deflected zenith in the Northern Hemisphere; to the left in the Southern.)

LATITUDE	GROUND SPEED — MILES PER HOUR				
	0	100	200	300	400
0	0′.0	0′.0	0′.0	0′.0	0′.0
30	0.0	1.1	2.3	3.4	4.6
60	0.0	2.0	4.0	5.9	7.9
90	0.0	2.3	4.6	6.8	9.1

Table VI (middle). For deflection of the plumb-line zenith due to horizontal curvature of course. (The plumb-line zenith is deflected toward the center of curvature.)

CURVATURE OF PATH, DEGREES PER MINUTE	VELOCITY — MILES PER HOUR				
	0	100	200	300	400
0	0′.0	0′.0	0′.0	0′.0	0′.0
1	0.0	4.6	9.1	13.7	18.2
2	0.0	9.1	18.2	27.4	36.5
3	0.0	13.7	27.4	41.1	54.7
4	0.0	18.2	36.5	54.7	73.0

Table VII (lower). For deflection of the zenith due to curvature of a path of constant azimuth: to be multiplied by the sine of the azimuth. (The deflection of the zenith is perpendicular to the course and on the side of the nearer pole.)

EFFECTIVE LATITUDE	GROUND SPEED — MILES PER HOUR				
	0	100	200	300	400
0	0′.0	0′.0	0′.0	0′.0	0′.0
20	0.0	0.0	0.2	0.4	0.6
40	0.0	0.1	0.4	0.8	1.5
60	0.0	0.2	0.8	1.7	3.1
70	0.0	0.3	1.2	2.7	4.8
80	0.0	0.6	2.5	5.6	10.0
85	0.0	1.3	5.0	11.3	20.1

DO YOU KNOW?

By L. J. Lafleur

TELESCOPE QUIZ

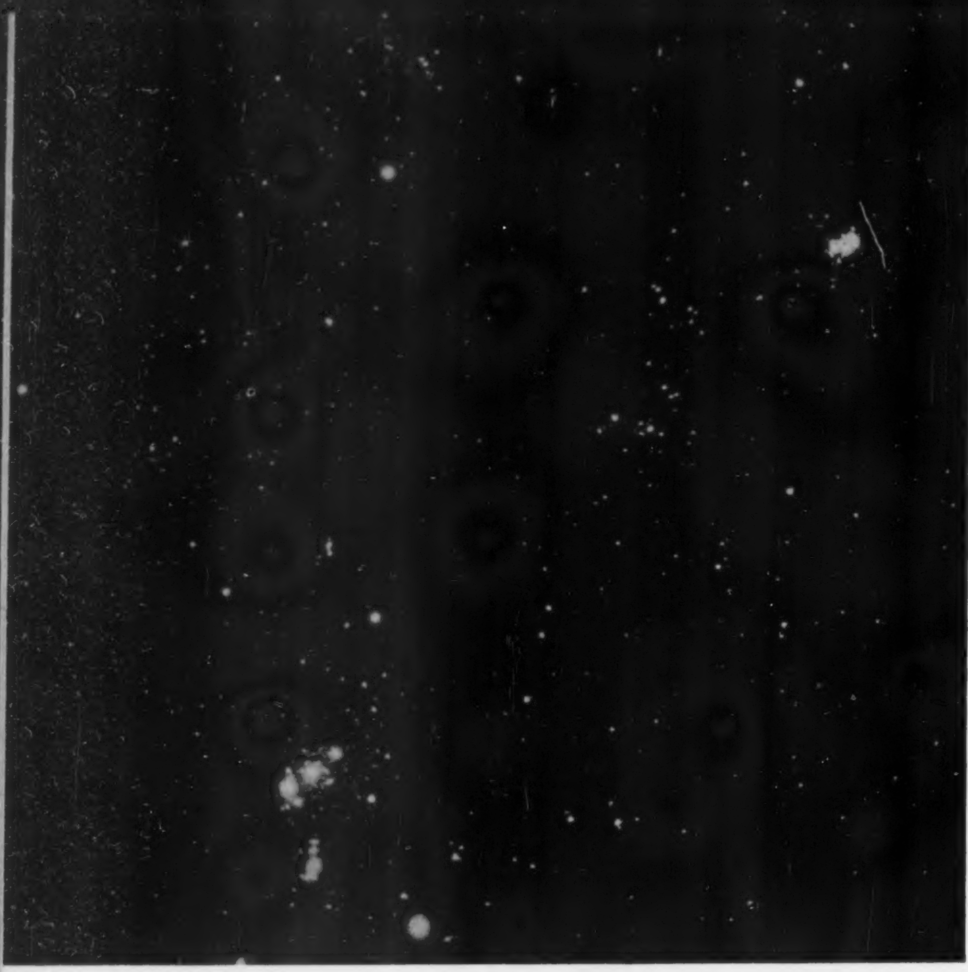
Count three points for each correct fill-in, whether of one or two words (total score, 102).

1. The most important power of a telescope is ...... power; then comes its ...... power; then its ...... power.
2. Magnifying power can be changed by using different ......; it is found by dividing the focal length of the ...... by that of the ....
3. A refractor is a telescope which uses a ...... to gather light, whereas a reflector uses a ......; usually the refractor has the longer ....
4. The principal types of reflectors are: ......, ..., ...; a ...... camera is a new modern type with very short ....
5. Aperture is the ...... of the ......, and focal ratio is the .... divided by the ......; refractors have .... of 15 to one, whereas ...... are usually ...... to one; the 200-inch is ...... to one.
6. Light-gathering power is proportional to the ...... of the aperture; resolving power to the ....
7. When a photographic plate is substituted for the ......, the ...... becomes a ......, but the plate must be in the ...., which in a Schmidt camera is ......, so the plate must be ...... to fit.
8. The Schmidt camera is featured by its large field of good ......, which in most reflectors is only about one ......; the mirror of a Schmidt is ......, but most reflector mirrors are ....

(Answers on page 22)

THE GAL

By E. G.



The Auriga-Taurus-Orion region of the Milky Way is rich in clusters. Orion is in the lower left, with Rigel at bottom center. The Pleiades are near the right edge, with the Hyades to right of center. Aldebaran, a red star, appears fainter than normal. M35 is just above a point halfway on a line from Alhena (γ Geminorum) at the left edge, center, to Nath (β Tauri), the bright star in the upper left center. Above Nath, M37, M38, and other Auriga clusters may be found.

FOR as long as men have looked at the night sky with the idea of studying its varied appearance, they have noticed the group of stars called the Pleiades. The Pleiades is a star cluster with an apparent diameter of from two to three times that of the moon; to the unaided eye it contains from six to a dozen stars depending on the darkness of the sky and the sensitivity of the eye. There are several other clusters visible to the naked eye, but they are not easily recognizable as such, either because they are much fainter and it is not possible to recognize individual stars, or because they occupy such a large area of the sky that no concentration is easily seen.

Under the first of the above two groups may be placed the Praesepe (Beehive) cluster, the double cluster in Perseus, the globular cluster in Hercules (M13), and Omega Centauri. All of these appear as hazy patches in the sky and are resolvable into stars only with the aid of a telescope. The second group includes the Taurus cluster, the Coma cluster, and the Ursa Major cluster. The Taurus cluster covers an area about 20 degrees across, and the story of its discovery will be taken up later. The Coma cluster, in the constellation Coma Berenices, is several degrees in diameter and appears at first glance as a chance grouping of stars. The stars in the Ursa Major cluster are found all over the whole sky. Its best-known members are five of the stars in the Big Dipper (the exceptions are Dubhe and Alkaid) and Sirius on the other side of the sky.

The difference in appearance of these clusters is due mostly to variation in distance, because most Milky Way clusters, or *galactic clusters,* as they have come to be known more recently, are of approximately the same linear diameter. Hence, the more distant the cluster, the smaller and more compact (and fainter) it will appear. As a matter of fact, the apparent diameter of a galactic cluster is a fairly good criterion of its distance. In the case of the Ursa Major cluster we are actually within the confines of the group, although our sun is not a member of it. The Taurus cluster, of the order of 20 degrees in diameter, is at a distance of 125 light-years; the Coma cluster is 10 degrees across and 250 light-years away; and so on for the more distant and smaller clusters.

Before we go any further, a distinction should be made between the galactic and globular clusters. The former are generally found to concentrate close to the Milky Way, or plane of the galaxy, while the globular clusters seem to avoid the Milky Way region. The globular clusters are the most distant, have larger linear diameters, and contain many more stars—perhaps up to several hundred thousand each. The upper limit to the number of stars in a galactic cluster is probably no more than a few thousand. The avoidance of the globular clusters for the Milky Way may not be real, but an effect of their great distances and the consequent greater absorption of their light by the material concentrated along the Milky Way. In directions above or below the Milky Way the absorption is much less, and the globular clusters stand out. If this absorbing material could be swept away, we would probably see globular clusters in the Milky Way, and for that matter, more galactic clusters. The distribution and number of galactic clusters will be discussed later, and nothing more will be said concerning globular clusters—although their story is tremendously interesting in itself.

Perhaps the two best-known galactic clusters are the Taurus cluster and the Pleiades. Both are in the same constellation. The former was discovered in 1908 by Lewis Boss, while the latter has been known for many thousands of years. The Taurus group contains that group of stars known as the Hyades, a V-shaped asterism of which the red star Aldebaran is one. It has been shown, however, that Aldebaran is not a member of the Taurus cluster, but that it is merely situated in the same direction.

The *proper motion* of a star is the result of that part of its space motion which is at right angles to the line of sight and which evidences itself as a gradual change of the star's position in the sky. Some years before Boss, R. A. Proctor had noticed what appeared to be a certain community of proper motion of some of the stars in Taurus.

In the early part of this century, Boss was working on his great catalogue of the proper motions of individual stars, the *Preliminary General Catalogue,* or P.G.C., as it is usually called. Finally in 1908, with the much more accurate and extensive material of his catalogue, Boss discovered 39 stars in this region, all of whose directions of motion seemed to converge at a point in the sky some distance away from the cluster. The cause for this convergence was immediately realized by Boss, who reasoned that all of the stars in the cluster have the same space motion, both in direction and speed, but that since the cluster is receding from us, the directions of motion appear to converge on a point. If the cluster were approaching us, the motions would appear to diverge.

ALACTIC CLUSTERS

Y E. G. EBBIGHAUSEN, *Allegheny Observatory*

To make this clearer, let us consider an analogy. Imagine yourself standing on a bridge that crosses over a number of parallel railroad tracks extending for miles in either direction. In the direction in which you are looking, there is a train far away on each track, and they are all approaching with the same speed. As the trains come nearer, they will appear to be diverging from a distant point, and will continue to separate until they have passed under the bridge. Then, as they recede, the trains will appear to converge toward a point in the distance opposite to the first. Hence, without knowing the line-of-sight, or radial, velocity of the cluster, we can tell that it is receding, and actual measures of its radial velocity confirm this. The confirmation comes independently of the foregoing observations, as spectroscopic determinations give us directly that part of a star's motion which is toward or away from us.

Since all of the stars of a cluster must have the same space motion (otherwise it would soon be dissolved), the problem of separating the cluster members from other stars in the same field is one of picking out those which have proper motions of the same value and direction. This community of motion applies also to the radial velocities, but as a rule these can only be determined for the brighter stars, while it is possible to determine proper motions for very faint stars.

Hence, in order for a star to be a Taurus cluster member, it must be moving toward the convergent, and have practically the same proper motion and radial velocity as the other cluster stars. It must also be at the same distance as the cluster, because it is possible, but rather improbable, for a star to satisfy the above three conditions and still be closer or farther away than the cluster. Since Boss' pioneer work on this group, the number of members has increased, due to the extension of the study to fainter stars—and still more work needs to be done with the aid of photographic plates which record very faint stars.

Since the publication of Boss' work on the Taurus cluster, other "moving" clusters have been discovered, particularly the already mentioned Ursa Major group, which extends over the whole sky, and a small cluster in the constellation Perseus.

A great deal of time has been expended on the Pleiades cluster, and the range in the brightness of the member stars is probably better known than for any other cluster. The most extensive research on the proper motions in the Pleiades region was completed somewhat more than 10 years ago by E. Hertzsprung, at the University of Leiden in Holland. His report on this work, given as the Darwin Lecture in 1929, is so interesting and clear that it would bear reading by anyone interested in astronomy. It is published in the *Monthly Notices* of the Royal Astronomical Society, Volume 89.

Hertzsprung's method for the determination of the proper motions in the region of the Pleiades was to compare the positions of the stars on an old plate with the positions of the same stars on a new plate, and thereby derive the motions. From various observatories he obtained about 40 pairs of plates, each pair consisting of an old and a new plate. The enormity of the task may be partially realized from the fact that his catalogue of stars in that region (two degrees in diameter) contains over 2,600 stars. Of all of the stars measured, only about 150 were found to be members of the Pleiades cluster, the remainder being field stars, that is, stars which to us are either closer or farther away than the cluster. The brightness of the cluster members ranges from the 3rd to the 16th magnitude, and Hertzsprung was

Small optical aid reveals many stars in the Pleiades, and nebulosity around some of the brighter members.

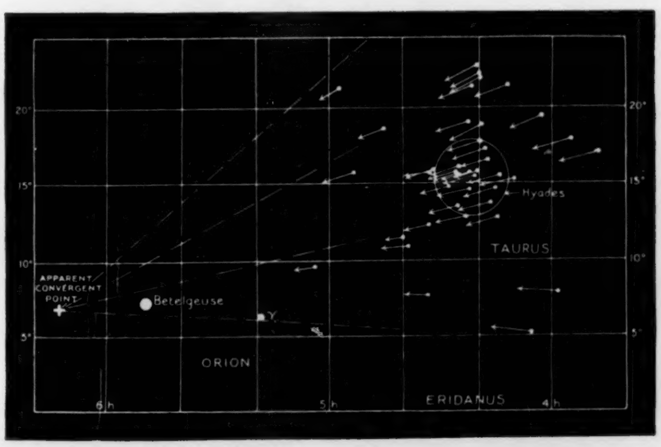
able to show that there must be many members which are still fainter, whose discovery awaits material from more powerful telescopes.

The main purpose of this proper-motion work on the cluster is, of course, to distinguish the cluster members from the field stars. However, if that were the end of the problem, it would hardly be worth doing. After the separation has been accomplished, the more interesting work begins, and several lines of investigation suggest themselves. One of these is to study the number of stars in the cluster within certain limits of magnitude. If the distance of the cluster is known, the true brightness of each star can be computed, and then this brightness distribution can be compared with that for stars in general.

Hertzsprung also measured the colors of the Pleiades members and found that in going from bright to faint stars, the color changes from blue to red. This is not true for all galactic clusters, since some of their brighter stars may be reddish in color. Other problems that may be mentioned are the distribution of the members in space about the center of the cluster, the change of spectral type with magnitude, and the small differences between the motions of the individual stars.

The last-mentioned problem is concerned with what is called the internal motion of the cluster. Its stars are not held rigidly in fixed positions, but are free to move about under the restriction of the gravitational pull of the whole cluster on its individual members. This results in a certain "swarming" effect, comparable to that of a swarm of bees moving through the air. The bees do not fly in rigid formation, but move about in random fashion, though never getting too far from the main swarm and always coming back to it. This is much the same situation as exists in a cluster, except that it is thought possible that a star may, by some external means, acquire such a high velocity as to escape entirely from the cluster and never come back.

The external means are seen as the disturbing tidal effect of the galaxy of stars



Here are plotted the proper motions of about 40 stars in the Taurus cluster. In addition to their convergence on a point in Orion, note small differences in the amounts and directions of motion for individual stars.

as a whole and the effect due to the close approach of stars which are interlopers in the cluster. If this situation exists, then clusters must be disintegrating, and consequently, a cluster will not exist forever. If new clusters are not being formed somewhere in the galaxy, then there is a distinct possibility that some billions of years in the future there will be no galactic clusters. The fundamental work on this subject has been done by Bart J. Bok, of Harvard College Observatory. A by-product of finding the degree of internal motion is an independent determination of the total mass of the cluster.

Early in this article, a reference was made to the absorbing material in the plane of the Milky Way and to the distribution and number of galactic clusters. Extensive research has been done on these problems by Robert J. Trumpler, of Lick Observatory. Trumpler's catalogue contains 334 clusters. His analysis of the material shows that these clusters are distributed in a flattened disk about 3,000 light-years in thickness and about 30,000 light-years in diameter. Furthermore, this disk lies almost in the plane of the Milky Way, and the sun is very close to the center of this "cluster of clusters."

However, it is a good practice to examine closely any situation in which the sun seems to occupy a favored position. Is the nearly central position of the sun real or illusory? Is the apparent thinning out of the clusters toward the boundaries of this group the true story? Part of this effect may be due to the fact that the more distant a cluster, the fainter, smaller, and less conspicuous it becomes against the background of many faint stars. Probably the interstellar haze plays an important role here also. Photographic plates taken with large-scale telescopes and sensitive to red light (which penetrates the haze more easily than blue light) might well reveal more distant clusters, particularly toward the galactic center. Nevertheless, the question of the reality of this system of clusters is not settled, and it is possible that the limits found by Trumpler are real.

Trumpler's work, largely unpublished, is concerned mostly with the number and distribution of these clusters, together with the magnitudes, colors, spectral types, and radial velocities of the cluster stars. Only a small amount of work is being done at the present time to determine proper motions of individual stars in clusters for the purpose of separating members and non-members. But to study a cluster properly, it is first necessary to effect this separation, and, as already indicated, this can be accomplished to a considerable degree by the determination of the radial velocities and proper motions of the individual stars in the region of the cluster. Radial velocities are, at present, limited to the brighter stars, but proper motions can be determined to much fainter limits. The latter study involves many difficulties, but it should be worth the effort. The relation of the problems of galactic clusters to those of the galaxy as a whole is so intimate that this work will undoubtedly continue to be an extremely fruitful branch of astronomical research.

ASTRONOMICAL ANECDOTES

A MATHEMATICIAN, PI AND RELAXATION

When the English were celebrating Christmas in 1642, Isaac Newton was born. In this department, in June of this year, a little was said about the falling apple tradition; recently I encountered another wise man's opinion on the subject. Once, the great mathematician Carl Friedrich Gauss (1777-1855), was asked about the story. "Silly!" he exclaimed. "Believe the story if you like, but the truth of the matter is this. A stupid, officious man asked Newton how he discovered the law of gravitation. Seeing that he had to deal with a child in intellect, and wanting to get rid of the bore, Newton answered that an apple fell and hit him on the nose. The man went away fully satisfied and completely enlightened."

This is quoted from Eric Bell's *Men of Mathematics*. In that large book there are numerous other intimate stories of the careers of the great mathematicians. Bell tells of Gauss and his reaction to Sir Walter Scott's novel, *Kenilworth*. The sad ending depressed the mathematician for days. But he was very fond of Scott's works, and once found the novelist saying, "the moon rises broad in the northwest," whereupon Gauss gleefully went about for days, correcting all the copies he could find!

While we are thinking of Gauss, whom many mathematicians today consider the greatest of all the illustrious men in their field, I am reminded of what one of my teachers, Prof. Norman Anning, used to tell each of his classes. "You are mathematicians in the direct line of descent from Gauss," he would say. "I have taught you, and I was taught by Perrot, who was taught by Kummer and Kronecker, who were taught by Dirichlet, who was taught by Gauss. So you are members of the sixth generation of the mathematical family of Gauss."

In August and October, this department carried some mnemonic devices for recalling the value of the mathematical constant π (3.14159...) to 30 places of decimals. If some wish to improve on those by extending them to more figures, they might like to know of William Shanks, who, in 1873, computed the value of π to 707 places! His work may be found in the *Proceedings* of the Royal Society of London, Vols. 21 and 22, pp. 318 and 45, respectively.

Pi appears also in the theory of probability, in addition to many other fields. For example, if two numbers are written down at random, the probability that they will be prime[1] to each other is $6/\pi^2$. W. R. Ball, in *Mathematical Recreations*, tells of 50 students, each of whom wrote down five pairs of numbers at random. Of these 250 examples of pairs, 154 were prime to each other. This represents a probability of 154 divided by 250, which would evaluate π as 3.12–pretty close for so few samples.

The obvious impatience Gauss felt for "stupid, officious" questioners is shared by some scientists today, I fear. This results in many of our current jibes at scientists, and even in some serious attacks on those who refuse to bring their thoughts instantly to the understanding of the questioner. Often, non-scientific persons want to be told "all about relativity in 50 words or less," without realizing that there are some such topics which cannot be described in simple terms, briefly.

Recently, I observed on a newsstand a popular monthly magazine which listed on its cover an article entitled, "Scientists are Lonely," or words to that effect. Perhaps scientists are sometimes intellectually lonely, but when it comes to relaxation, they are usually excellent company. For instance, there is no more happy crowd than the American Astronomical Society during the informal events of its meetings.

At the 43rd meeting of the society at Harvard 13 years ago, the old year was hurried on its way with the premier presentation of "The Harvard Observatory Pinafore," written by Winslow Upton in 1879, from which we extract only a small fragment, describing the astronomer:

His knees should bend and his neck
should curl,
His back should twist and his face
should scowl,
One eye should squint and the
other protrude,
And this should be his customary
attitude.

In somewhat the same vein, some members composed and performed "The Story of Frederick," at the 66th meeting of the society at Yerkes Observatory in September, 1941. Next month you shall have it.

R.K.M.

[1] Numbers are *prime together* or *relatively* if they have no common denominator except the number 1; for example, 12 is prime to 25.

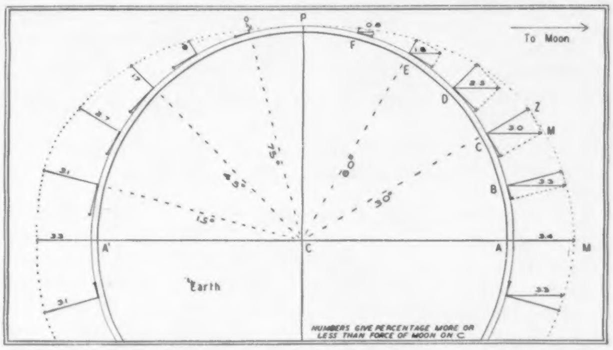
BEGINNER'S PAGE

By Percy W. Witherell

Tides the World Over

In our discussion of tides last month, we proved that the differential pull of the tide at a point on the earth's surface nearest the moon exceeds that at the earth's center by 3.4 per cent. Furthermore, at a point on the earth's surface opposite to the first the pull is 3.3 per cent less than at the center, thereby producing the tide opposite to the moon.

But these are special cases of the tidal problem for the entire earth. It can best be understood by resolving the tidal force at any place into two components. One component will be perpendicular to the surface and is the tide-raising force, while the other will be tangent to the circumference of the earth and drive the water along the surface, producing a current.



The tidal force produces a lifting of the water and a horizontal movement. The complete parallelograms of force are shown for one quadrant only, to avoid confusion. The light dotted line joins the tops of the vertical, or tide-raising forces.

The diagram shows the two components for 15-degree intervals of latitude when the moon is in the zenith at the equator, a condition which occurs twice each month. At A, on the equator under the moon, the entire force is perpendicular to the surface, and the vector there, AM, represents the differential (3.4 per cent) between this force and that at the center of the earth. Similarly, at A′, on the opposite side of the earth, the vector shows the tide-raising force away from the moon.

For a point such as C, the latitude is 30°, so its distance from the equator is about 2,000 miles. Its distance from the moon is about 500 miles greater than that of A, so the tidal pull is reduced to about three per cent of that at the center of the earth. The vector CM is therefore slightly shorter, but its horizontal component is 1½ per cent of the tide at C. At D, latitude 45°, the horizontal and vertical components are equal, and the total force is 2.5 per cent that at C.

Further study of the diagram shows how the theoretical shape of the tides is produced, since only the component perpendicular to the surface can be considered as *raising* the water's level.

In actual cases, however, the theoretical shape is far from being achieved, owing to a multitude of factors, chief of which is the division of the water-covered earth by its large land masses. Twice a day at about the full of the moon, a main tide or *parent* wave starts north and west on a line from Balboa to Honolulu. Three or four hours later the northward portion has reached Victoria and Dutch Harbor, and the westward, Kamchatka and New Zealand. Far south, not distant from the coast of Chile, another tide wave starts east and south, passes around Cape Horn and combines with a northwestward wave in the Atlantic which has come around the Cape of Good Hope. This combined wave arrives on the Atlantic coast of the United States about seven hours later. Meanwhile, in the northern Atlantic, a wave starts off the Azores and travels around the British Isles to Norway. Another wave is one which travels westward from a region south of Australia and thence northward into the Indian Ocean.

Due to different ocean depths, these waves travel at very different speeds, so that the wave reaches Boston 40 hours and the Baltic 60 hours after its origin in the Pacific. At the extremity of its travel up the Amazon River, the tide wave is four days old from its birth in the Pacific.

In the depths of the oceans the tidal friction is small, but in the narrow bays and channels it is very great, totaling over 1,500 million horsepower. The energy required is obtained from a slowing down of the rotation of the earth and a consequent lengthening of the day. But as this is only about 1/1,000 of a second per century, it need not disturb us. Over the long span of the life of our planet, however, this change in the period of its rotation has produced tremendous results.

The total angular momentum of the earth-moon system must remain unchanged, so when the earth slows down, the moon must speed up to absorb the added momentum. This causes it to strain outward on the earth's gravitational leash, and the moon's orbit is thereby enlarged. But a larger orbit requires more time for the moon to traverse, so the month is getting longer with the day, but at a much slower rate.

Looking backward 4,000 million years (which may be before the earth was born), we can imagine a globe which rotated in a little less than five hours, with its satellite about 9,000 miles away and the month (period of revolution of the moon) a little over five hours in duration. Gradually, tidal friction has altered this state to that of the present, but if we look what is almost an interminable time into the future, the day will have become equal in length to 47 of our present days, and there will be only eight days in a year! Meanwhile, the lengthening month will also occupy 47 of our present days, so the day and month will be equal.

Under these circumstances, the earth will keep the same side toward the moon, as the latter does to the earth at the present time. All this supposes, however, that the oceans are still liquid and exerting tidal friction. It therefore becomes purely imaginative to say, as some have, that the further effect of solar tides, still supposedly operating, will be to start the moon moving inward to the earth again, eventually to approach so close that gravitational forces within it will tear it to pieces. This interesting and somewhat mathematical possibility would leave the earth with a ring like those around Saturn, composed of tiny meteoric particles.

Index Announcement

A title page and working index to Volume I of *Sky and Telescope* is now in press. It will be ready for distribution by December 1st. It will include author, title, subject and topic references, adding considerably to the usefulness of the year's issues. Because of the increased cost of printing this more elaborate index, a charge of 25c a copy postpaid is made for it, which may be sent in coin or stamps. Please send your orders in promptly. ED.

BOOKS AND THE SKY

FROM COPERNICUS TO EINSTEIN

HANS REICHENBACH. (Translated by Ralph B. Winn.) The Philosophical Library, New York, 1942. 123 pages. $2.00.

PROF. Hans Reichenbach is well known to scientists and philosophers as one of our most distinguished writers on the subject of the philosophy of science. His writings (in German) hold an eminent place in the literature of his subject, especially in probability and contemporary physics. It would be a real service if some enterprising publisher would bring out English translations of these works, especially his *Philosophie d. Raum-Zeit-Lehre*, one of the very finest discussions of the logic of relativistic physics.

The present book may best be described as a popular account of the various reasons behind the development of the physics of relativity. It presents in clear and logical order the mechanical, the astronomical, and the electromagnetic bases of the ideas and, in addition, sketches the historical outline of the problems concerned. The presentation is free from the common misinterpretations of relativity and should be an ideal introductory work for those readers who are unfamiliar with the main ideas in the restricted and general theories. However, since there are many such books, one questions the value of publishing another, especially when Prof. Reichenbach's more useful work on the subject (cited above) remains as yet unavailable.

The translation is at most a fair job, since the translator does not appear to be familiar with standard English expressions. For example, the distinction between gravitational and inertial mass is rendered as one between "heavy" and "inert" mass. The first four satellites of Jupiter, called by their discoverer, Galileo, the "Medician planets," or "Medician stars," are here called "medizeic" stars. Kepler's three laws are referred to between quotation marks as "the Kepler's laws," and so on. One is thus led to regret that Prof. Reichenbach's introduction to American readers is not at all commensurate with his great achievements and his scientific stature.

I. BERNARD COHEN
Harvard University

THE CRUX OF CHRONOLOGY

FRANK HERMAN MEYER. Bruce, Humphries, Inc., Boston. 599 pages. $3.00.

BY a quotation from the jacket of Frank Herman Meyer's *The Crux of Chronology*, the purpose of this book is no doubt best expressed. "I do believe that some day, somewhere, a literary genius will arise who, on the basis of my book, will produce the greatest book of the twentieth century—a true, historical, lifelike biography of Jesus Christ." The author has no doubt spent a great deal of effort in gathering and documenting the wealth of data its 600 closely printed pages contain.

The book is in five parts or volumes. The first deals with the various eras; the second mainly with the succession of the Roman consuls. The third is rather hard to caption (the author does not caption any of them). The fourth and fifth deal more directly with the life of Jesus Christ.

In the introduction, the author speaks of "sacred" chronology, and perhaps, that word should have been incorporated in the title. The book is pointed definitely to the "chronology pertaining to the life and times of Jesus called the Christ." The pace is rather breathless. From the first sentence to the last, excerpts, data, computations, conclusions, follow in rapid succession. One subject is dropped and another picked up. The work is meaty and without frills.

I found a great many interesting bits that dealt with astronomical phenomena along the trail of history. But I doubt that I can ever find them again without looking through the entire book. There is no index. And if ever a book needed one, this one does. Why do publishers and authors release books without indices?

At random I open to page 503 and quote one short paragraph:

"Upon the presentation of these facts and figures, there is no other but purely supererogatory work to be done. Even that small modicum of effort may be reduced to the minimal remark that only 41 A.D. presents the features of calendric arrangement required by the biblical narrative. According to the Jewish, or Syro-Macedonian calendar, the sixth day of Daesius (or Sivan), the festival of Pentecost, was the fourth day of the week, or, to be precise, the fourth

day of the 10667th week of the Asmonean-Herodian Era. According to the Julianized Romand Calendar, the 146th day of the eighty-sixth year of Julius Caesar's Calendar was a Wednesday, Cal. C, being May twenty-sixth, J.P. 4754 or 41 A.D."

WILLIAM H. BARTON, JR.
Hayden Planetarium

NEW BOOKS RECEIVED

DOWN TO THE SEA, *Louise Hall Tharp*. 1942, *McBride*. 242 pp. $2.00.
A biography of Nathaniel Bowditch for young people, which proves to be a lively account of the great American's life and work.

THE PRACTICAL ESSENTIALS OF PRE-TRAINING NAVIGATION, *Skilling and Richardson*, 1942, *Holt*. 113 pp. 75 cents.
A paper-bound book gives a quick look at the principles and practice of celestial navigation. Problems are included. Map projections and meteorology each receive a chapter's discussion.

THE AMATEUR SCIENTIST, *W. Stephen Thomas*. 1942, *Norton*. 291 pp. $3.00.
This book is based largely on the work of the Committee on Education and Participation in Science, which has been investigating amateur science in the Philadelphia area for several years, and of which the author was executive secretary. The author discusses the amateur in science, who he is, how and where he works, and how he contributes to the advancement of knowledge.

THE ORIGIN OF THE CAROLINA BAYS, *Douglas Johnson*. 1942, *Columbia*. 341 pp. $4.50.
A thorough study of the controversial Carolina bays and of theories which have been advanced for their origin causes the author to offer and support a "hypothesis of complex origin" (the "artesian-solution-lacustrine-aeolian hypothesis"). The meteoritic hypothesis is discussed at some length, and this author is forced to discount it.

ROEMER AND THE FIRST DETERMINATION OF THE VELOCITY OF LIGHT, *I. Bernard Cohen*. 1942, *Burndy*. 63 pp. 50 cents.
A pamphlet on this discovery and its historical background includes an account of other phases of Roemer's work. The pamphlet is reprinted from an issue of *Isis*, a Belgian publication, which appeared after the invasion, and only eight copies of which have thus far found their way to the United States. The author concludes with this paragraph:

"Roemer was too modest to demand for himself any glory or praise from his contemporaries; he was too busy to be able to devote any of his time to the spreading of his ideas. Calamity seems to have conspired with fate to prevent the dissemination of his work after his death so that Roemer, considered by his contemporary scientists to be one of the leading figures of his age, is today known generally only because of his discovery of 'mora luminis' and for the first determination of the velocity of light."

Amateur Astronomers

LETTER TO THE EDITOR:

"Subject to revision according to audience reaction, plenty of which we hope to receive from readers who use them regularly." Criticism is very difficult at any time unless one has a better idea and I am afraid I have little to offer, but here goes:

I am glad that the cover stock now used on *Sky and Telescope* is stronger as the thin paper of former issues easily tore. The plate reproductions on back pages are well rendered and the magazine cleanly printed in general and its contents just about technical enough for the general reader—in fact some are beyond me as I am not much at "figgers."

Now in regard to the newly designed star map in the November issue, I must state that it now contains something worth looking at on rainy nights! Star maps are very difficult to make readable and yet contain much. What is gained by one arrangement is lost in another design and so on. Instead of joining the stars in the constellations by dotted lines, straight, faint lines give a better grouping. The subject of this map is *stars*, and therefore, if the stars were drawn a little larger, and the name of the constellation written in condensed capitals preferably in the center of the constellation, it should enhance the appearance to a great extent.

The circles denoting the various horizons might be more effective if they were fine dotted lines, even horizon 40°. It is true that some constellations are spattered over all creation and hence the name is generally put in extended letters, but I still think this adds to jumbling up the space . . . .

I was most surprised in reading the article by Mr. Fitzpatrick on Omega Centauri in the June issue wherein he states that he saw this star cluster from the latitude of New York! I had no idea it was visible this far north, but will look for it next summer. I have seen Omega Centauri from Key West and also from Rio de Janeiro, but in southern climes the mosquitoes generally detract from the study of astronomy.

Saturn shows up well these years . . . . I had not much difficulty in just seeing the rings this week with an 18x50 Zeiss binocular. In my 4¼-inch refractor, it may be magnified well 100 times and show good detail. Low powers are generally best.

CHARLES M. PAULUS
Sinking Spring, Pa.

DETROIT ASTRONOMICAL SOCIETY

The monthly lectures at the meetings of the Detroit Astronomical Society have been designed to cover a study of the sun and the solar family extending from October through January. The opening talk in October was delivered by Prof. W. Carl Rufus, director of astronomy at the University of Michigan. His illustrated lecture on *The Wonders of Our Sun*, with the assistance of Dr. E. R. Phelps, of Wayne University, laid the groundwork for the series.

Prof. Robert R. McMath, director of the McMath-Hulbert Observatory, assisted by Dr. Orren Mohler, demonstrated, on November 8th, the latest solar films to be released at McMath-Hulbert.

MARGARET BACK, secretary

AMATEUR ASTRONOMERS ASSOCIATION
New York City

On December 2nd, Dr. Clyde Fisher, honorary curator of the Hayden Planetarium, will speak on *The Einstein Theory Today*; and on December 16th, the society will engage in an Astronomical Question Bee with members of the Junior Astronomy Club. These meetings are held in the American Museum of Natural History, at 8:15 p.m., and are open to the public.

For information regarding membership, meetings, classes, field trips, and other association activities, address the secretary, George V. Plachy, at the Museum.

GLEANINGS FOR A. T. M.s

EDITED BY EARLE B. BROWN

DESIGNING AN ACHROMATIC OBJECTIVE—III

(Continued from the October issue)

6. Special Cases. Before we leave the subject of fundamental equations, there are two special cases we must consider. The first is that of rays parallel to the axis. This is of particular importance in astronomical objectives, as in such cases we shall always begin our computations with such rays. Here, **L** is infinite and **U** is zero, and equation (1) becomes insolvable.

Consider Figure 4. It is evident that equations (2) to (5) are still valid. Now, angle

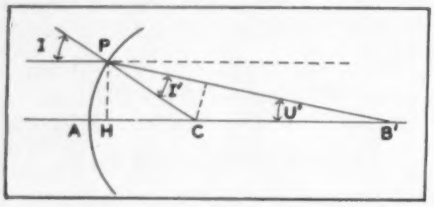


Fig. 4. Rays parallel to the axis.

PCH = I, hence sin I = PH/r. Designating PH=Y, we have sin I = Y/r (1 par). In our computation in Table III, we begin on line 6 by entering log **Y**. The rest of the computation proceeds in the usual manner.

The second case is that of a plane surface, where **r** is infinite, and equations (1) and (4) become meaningless. This case is illustrated in Figure 5. For equations (4) and (5) we have **L′** = PA/tan **U′** or **L′** = **h**/tan

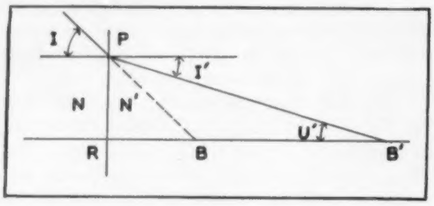


Fig. 5. The case of a plane surface.

U′; for equation (3) we have **U′** = —**I′** (3pl). Equation 2 is still valid, and for equation (1) we have **h** = **L** tan **U** (from **I** = —**U**). This changes our computation

Table III

Quantity	COL. 1 Marginal Ray 1st.Surf.	COL. 2 Marginal Ray 2nd.Surf.	COL. 3 Paraxial 1st.Surf.	COL. 4 Plane Surface
1 L	20.000	17.703	Same	20.000
2 -r	-15.000		"	
3 L-r	5.000		"	
4 log (L-r)	0.69897		"	
5 +log sin U	+8.71880	8.76567	"	
6 log (L-r) sin U(or Y)	9.41777		"	
7 -log r	-1.17609		"	
8 log sin I	8.24168		"	8.71880n
9 +log N/N'	-0.18184		"	-0.18184
10 log sin I'	8.05984		"	8.90064n
11 +log r	+1.17609		"	
12 log r sin I'	9.23593		9.23593	
13 -log sin U'	-8.76587		-8.76574	
14 log (L'-r)	0.47026		0.47019	
15 U	3°00'00"	3°20'32"	.05234	
16 +I	+0 59 59		+.01745	
17 U+I	3 59 59		.06979	
18 -I'	0 39 27		-.01148	
19 U'	3 20 32		.05831	
20 L'-r	2.955		2.953	
21 +r	+15.000		+15.000	
22 L'	17.953		17.953	13.134
23 -d	-.250		-.250	-.250
24 L_1	17.703		17.703	12.884
25 log L				1.30103
26 +log tan U				+8.71940
27 log L tan U				0.02043
28 -log tan U'				-8.90203
29 log L'				1.11840

table considerably, as illustrated in Table III, column 4, assuming we use the same columnar sheet on which the other computations are entered. The sample case is **L** = 20.000 m/m, **U** = 3° 00′ 00″, **N′** = 1.5200. We add lines 25-29, and use only lines 8 to 10 of our original form.

7. The Primary Aberrations. The six primary aberrations, in the order of their importance in astronomical objectives, are:

a. Chromatic aberration
b. Spherical aberration
c. Coma
d. Astigmatism
e. Curvature of field
f. Distortion

Chromatic aberration. The refractive index, **N**, of any medium is not a constant for all wave lengths of light, but is greater the shorter the wave length. Hence, the focal length of a lens is shorter for violet light than for red light (Figure 6). To state this more rigorously, the refractive index is an increasing function of the frequency. The result is that while a lens will give a sharp image of an object illuminated by monochromatic light, the image in white light will be spread out along the optical axis and the definition ruined. The effect is more pronounced the shorter the mean focal length of the lens, which fact accounts for the tremendous focal lengths (200 feet and more) used in early telescopes before the principle of achromatism was discovered, about 1760.

This principle, of course, is the use of two-component lenses. The refractive-index function (dispersion), while always an increasing function of the frequency, does not increase at the same rate for different types of glass. In so-called "dense" glasses, the function increases more rapidly than in "light" glasses. Hence, by combining a positive lens of light glass with a negative lens of dense glass, it is possible to neutralize the chromatic aberration without destroying the converging power of the lens as a whole. When the light passes from the light glass

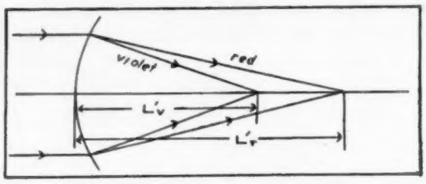


Fig. 6. Chromatic aberration.

to the dense glass, the rays as a whole are spread, because the dense glass is a negative, or divergent, lens. But the violet light is spread more than is the red. Now, if the two glasses had the same refractive function, the two colors would be brought together again only at the cost of all the convergence; that is, the emerging rays would be parallel to the entering rays, and there would be no image. But, if the negative lens has a greater dispersive power than the positive lens, the two colors can be brought together as an image on the optical axis (Figure 7). Our job, as designers, is to so balance the curvature of the two lenses that the desired coincidence is attained. Further discussion of this must await presentation of the simplified equations for lenses.

We will define chromatic aberration to be the distance between the paraxial intersection-lengths for the two wave lengths of light being considered, and it is $l'^r - l'^v$. Hence it has positive sign if the focal point of red light lies to the right of the focal point of violet light.

In the two-component lens, only two specific wave lengths of light can be brought

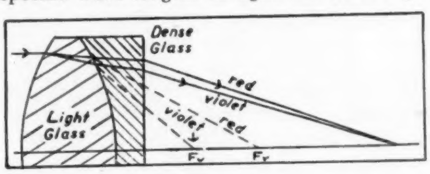


Fig. 7. Correction for chromatic aberration.

into coincidence; the remainder of the spectrum is out of focus at the image point. But this is usually sufficient correction, as the extraneous colors are generally confined to a small region about the principal image, and are not sufficiently strong to influence definition appreciably. In camera objectives, it is sometimes desired to bring three colors to a single focal point, and to accomplish this, three-component lenses must be used.

(Next installment in February)

RELATIVITY

(Continued from page 8)

100-inch telescope at Mt. Wilson Observatory, has succeeded in obtaining the companion's spectrum and in measuring the Einstein shift in its lines. The average value he obtained was 0.32 angstrom, almost in exact agreement with the prediction.

The actual isolation of this Einstein shift from the spectrum of any ordinary star is very complex. There are many sources of small red shifts which interfere with each other. But the Einstein effect for the white dwarf stars, of which Sirius' companion is the classical example, is of the same order of magnitude as the easily observed Doppler shifts caused by ordinary stellar radial velocities. Therefore, the observations made by Adams are conclusive. This, then, is another proof of Einstein's principle of equivalence and of general relativity principles.

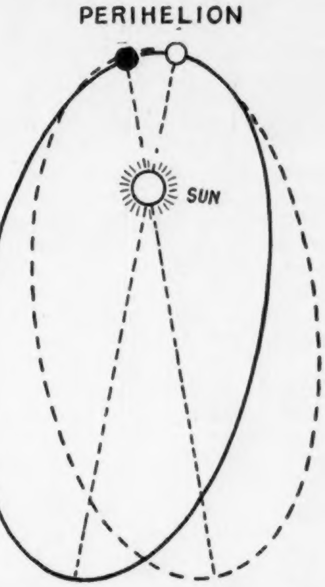
10. The advance of Mercury's perihelion

As is stated in Part II, the observations of the deflection of starlight by the gravity of the sun prove that the field of gravity must be different from the field ascribed by the Newtonian law of attraction. Particularly at points of great gravitational intensity these departures must be considerable. Nevertheless, the conclusions drawn from Newtonian laws have been in marvelous agreement with astronomical observations of the orbits of the planets. But for at least a century there have been some flaws, particularly concerning the orbit of Mercury, which is nearest to the sun, and therefore in the most intense field of gravity, and it is this which Einstein's new principles succeed in explaining.

If a planet is attracted by a center of mass in exact accordance with Newtonian law, its orbit is an ellipse which keeps its location in space. We observe that the orbits of all planets gradually change their positions in space—that is, the major axis of each elliptical orbit performs a slow rotation in the plane of the orbit. This results in a change in the location of perihelion (the point in the orbit nearest the sun) and we speak of this change as the advance of perihelion.

This advance was ascribed by Newton and his successors to the attraction of a planet by its fellow planets—the law of gravitational force is really one of attraction toward many centers. But the solar attraction prevails and the orbit of each planet is nearly a stable ellipse. The effect of the other planets is just a perturbation, which is noticed as the advance of the perihelion. If we calculate from Newton's law of universal attraction the value of this effect for each planet in turn, we obtain values which are, generally, in exact agreement with observation.

But Mercury is a conspicuous exception, as its perihelion advances 574 seconds of arc per century, which is about 43 seconds of arc *more rapidly* than can be accounted for by perturbations of the other planets. Astronomers looked for an explanation of this "flaw" in universal gravitation for over a century, until Einstein was able to show that the same "curvature of space" which accounts for the doubling of the deflection of light (see Part II) explains this 43 seconds' advance of Mercury's perihelion. To discuss in detail why this is so would require our going deeper into the theory of the curvature of space than we are able to do here.



11. Conclusion

It is seen that relativity is one of the most amazing achievements of the scientific mind in this century—three different phenomena, the deflection of light rays in a gravitational field, the change of frequency of light in a gravitational field, and the additional advance of the perihelion of Mercury, were derived from one and the same hypothesis. This was Einstein's "equivalence of gravity and inertia." This achievement is the more astonishing as the effect of gravity upon light had not been predicted before even qualitatively.

Prof. R. C. Tolman, of California Institute of Technology, remarks correctly: "Einstein's development of his theory was the full flowering of a . . . structure growing from principles whose main justification seemed to lie in their inherent qualities of reasonableness and generality. The extraordinary success of a theory obtained by these methods of intellectualistic approach, whose dangers have been so evident since the time of Galileo, well bespeaks the genius of the founder."

LANTERN SLIDES

Subscriber B. L. Harrell, 105 N. 10 St., Gadsden, Ala., writes that he has six hand-colored lantern slides of constellation charts similar to the one which appeared on page 12 of the September issue. These he will very gladly lend to any responsible person or association provided they pay the postage both ways.

The Starry Heavens in December

By Leland S. Copeland

Three Magi and the Advent Star—The Giraffe That Was Once a Camel—Six Other Eye-teasing Constellations

THE Star of Bethlehem brightens the night sky of December. Usually, it is known by its pagan name, Sirius, "the shining one." Beautiful above all other stars, it gleams in the southeast. And preceding it, outriders on its northwest flank, are the Three Wise Men, Gaspar, Melchior, and Balthasar, or, as they ordinarily are called, Mintaka, Alnilam, and Alnitak, the belt stars of Orion (named from west to east). But of course all of this is just poetry.

Biblical Nativity stories show that the great Galilean teacher was not born in December. "There were...shepherds keeping watch over their flock by night." This picturesque detail indicates the warmer period of the year. The rainy season of Palestine, November to March, is unfavorable for nights in the field. So it is unlikely that Jesus was born at the winter solstice, the birth-time assigned to the sun gods of Greece and Persia.

In the Gospel narrative, we read that as the Magi rode toward Bethlehem the Star went before them and that at last it stood above the manger. No heavenly body known to astronomers could move south and then glide back northward to the zenith. The star in the east was either legend or miracle, not a natural object.

It could not have been a comet, as depicted by J. Portaels in his painting of the Three Wise Men. Comets, to all ancient minds, foretold disaster. Conjunction of planets? Improbable, as planets do not remain in actual conjunction long enough. Venus? The Magi were star students; though astrologers, they would have known the brightest planet.

But these considerations cannot prevent poetically-minded persons from seeing in Sirius the ever-recurring December representative of the Star of Bethlehem. On December 25th Sirius shines all night. It is on the meridian at 12:30 a.m. (add one hour for war time).

Holy Writ, which gave us so many earthly place names, failed to influence the nomenclature of the sky. This is because for 1,000 years the Church neglected the celestial sphere. In the Middle Ages, Mohammedans were champions of astronomy, as many star names and the words, *zenith* and *nadir*, still remind us. In the list of constellations we find only two that can be called Biblical: the Southern Cross and Columba, Noah's Dove. Columba was approved in 1661 by Jacob Bartsch, German mathematician and son-in-law of Kepler.

He also found in the sky the camel that bore Rebekah to Isaac, but this dromedary became Camelopardus, or Camelopardalis, the camel-leopard or giraffe. Look for it above Auriga and Perseus, between Ursa Major and Cassiopeia. There are six stars of about the 4th magnitude; the others are less luminous. So any patient observer can see how keen-eyed and imaginative was Kepler's son-in-law.

In the December heavens are three other eye-teasers—Monoceros, following Orion; Lynx, between Auriga and Ursa Major; and Lacerta, across the Milky Way from Cepheus. For Monoceros, we can thank Jacob Bartsch. To see Lynx, some wag has explained, one must be lynx-eyed. This constellation was defined in 1687 by Johannes Hevelius, who at the same time marked out Lacerta, Leo Minor, Sextans, and Vulpecula, all tests for unaided eyes.

Winter's brightest candles flame in the night sky of early December; 11 of the 20 stars of 1st magnitude can be seen at one time. Fomalhaut, Altair, and Vega are about to dip behind the western rim. Deneb, tail star of the Swan, shines in the northwest. In the eastern half of the heavens sparkle Capella and Aldebaran, Betelgeuse and Rigel, followed by Pollux, Procyon, and Sirius.

SEEIN' THINGS AT NIGHT

"AND he had in his right hand seven stars." Among starry sevens, including the Pleiades and the Dippers, no group is more magnificent than the seven great suns of Orion, two of the 1st magnitude and five of the 2nd. With such marvels in the heavens, no wonder the Sumerians and their intellectual descendants, the Jews, thought that seven was the perfect number. The book of *Revelation* mentions 18 varieties of seven.

As we look heavenward in December we cannot help seeing the bright stars of Orion. Betelgeuse, a red beauty in the giant's eastern shoulder, is actually more insubstantial than a ghost—it is as empty as a laboratory vacuum. But its enormous size compensates; it is one of the largest suns in our Milky Way system. Betelgeuse means *armpit of the central one.* The *e*'s are short. Accent the first syllable and pronounce the last as *juz*, with the *u* long, as in *u*nite.

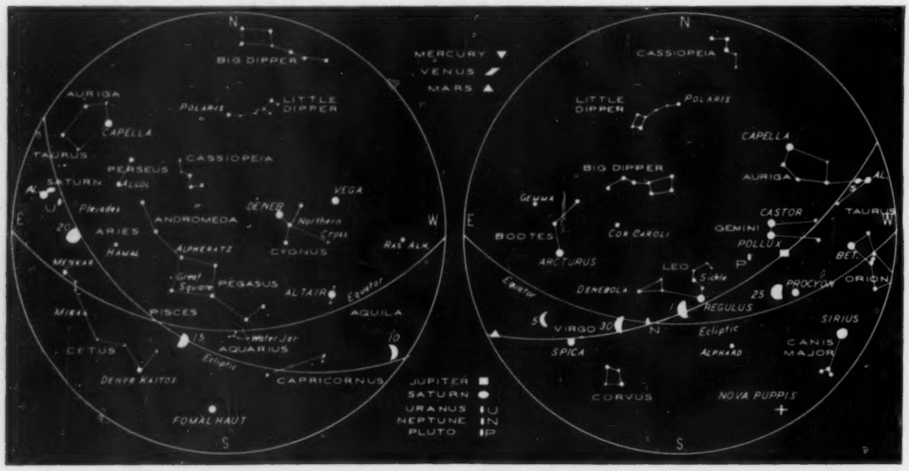
Diametrically opposite, across the rectangle of Orion, is Rigel, meaning *foot.* The *i* is long and the *g* soft. Rigel is a great blue star. When seen through a telescope, it is found to have a small companion, which rests above it like youthful Kedalion on Orion's shoulders. (Recall how Kedalion guided the blinded giant to the healing rays of the rising sun.)

In Orion's western shoulder shines Bellatrix, Latin for *woman warrior,* and on his eastern leg is Saiph (two syllables), meaning *sword.* Stress the second syllable of Bellatrix and make the *a* long. The belt stars, from west to east, are Mintaka (*belt*), Alnilam *(string of pearls),* and Alnitak *(girdle).* Mintaka and Alnilam are accented on the first syllable; Alnitak, on the last (Webster).

DEEP-SKY WONDERS

FOR several thousand years men studied stars without optical aid, yet in that huge interval they learned a great deal about the stars. So do not neglect the heavens if at present you do not own a telescope. Garrett P. Serviss wrote a book called *Astronomy*

THE NOVA, MOON, AND PLANETS IN THE EVENING AND MORNING SKIES



In mid-northern latitudes, the sky appears as at the right at 6:30 a.m. on the 7th of the month, and at 5:30 a.m. on the 23rd. At the left is the sky for 6:30 p.m. on the 7th and for 5:30 p.m. on the 23rd. The moon's position is marked for each five days by symbols which show roughly its phase. Each planet has a special symbol, and is located for the middle of the month, unless otherwise marked. The sun is not shown, although at times it may be above the indicated horizon. Only the brightest stars are included, and the more conspicuous constellations.

Mercury, which on November 30th was in superior conjunction with the sun, cannot be seen by amateurs this month.

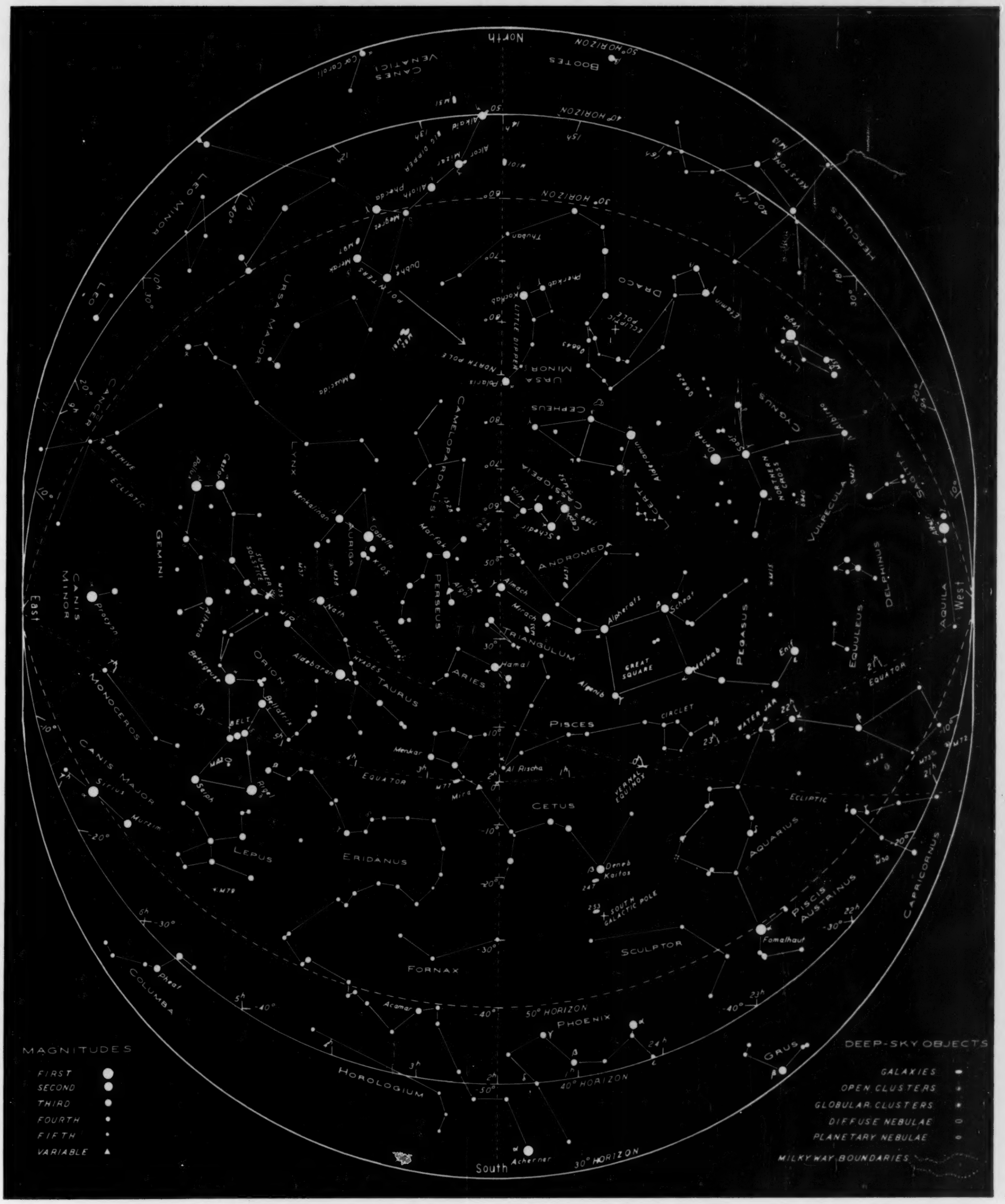
Venus is in the evening sky, too close to the sun to be seen.

Mars, at the end of the month, will rise two hours before the sun, but its great distance makes it comparatively inconspicuous.

Jupiter, evening star, is moving westward (retrograding) in Gemini. It is very striking, magnitude, —2.2.

Saturn is in Taurus, close to and brighter than Aldebaran. It is also moving backward, and is in opposition to the sun on December 1st; its distance from us is about 750 million miles. The rings are well opened for observation, inclined at about 26 degrees to our line of sight.

Uranus is in Taurus, at $3^h\ 59^m$, $+20°\ 22'$ on the 15th; while *Neptune* hides in Virgo, at $12^h\ 9^m$, $+0°\ 27'$. *Pluto,* now in Cancer, is 15th magnitude, visible only in large telescopes.



with the Naked Eye. That should reassure you. There is much for unaided eyes to see, and still more for those who have opera or field glasses.

If you own a telescope, this month look for the following:

Diffuse nebulae: M42, Orion, 5^h 31^m, —5° 26′; M43, mitten-shaped, following M42; M78, Orion, two interpenetrating lobes, 5^h 42.6^m, +0° 02′.

Galaxies: N.G.C. 247, Cetus, 0^h 44.6^m, —21° 01′; M81, Ursa Major, 9^h 51.5^m, +69° 18′; M82, close to M81 and much easier to see. M82 is handsome, irregular, looking like an edge-on nebula.

Planetaries: M76, Perseus, 1^h 39^m, +51° 18′; M1 (Crab), Taurus, 5^h 31^m, +21° 59′.

Globular: M79, Lepus, 5^h 21.9^m, —24° 34′.

Clusters: M34, Perseus, 2^h 35.6^m, +42° 21′; N.G.C. 1528, Camelopardalis, 4^h 7.6^m, +50° 59′; N.G.C. 7789, Cassiopeia, 23^h 52^m, +56° 10′.

THE STARS FOR DECEMBER

as seen from latitudes 30° to 50° north, at 10 p.m. and 9 p.m. on the 7th and 23rd of the month, respectively. The 40° north horizon is a solid circle; the others are circles, too, but dashed in part. When facing north, hold "North" at the bottom, and similarly for other directions. This is a stereographic projection, in which the flattened appearance of the sky itself is closely reproduced, without distortion.

OBSERVER'S PAGE

By Jesse A. Fitzpatrick

All times mentioned on the Observer's Page are Eastern war time.

Aldebaran, Regulus, and the Moon

Only four of the 1st-magnitude stars, Aldebaran, Antares, Regulus, and Spica, lie close enough to the ecliptic ever to be occulted by the moon. At present, the latter's constantly shifting path lies close enough to Aldebaran and Regulus so that these two stars are each in a series of occultations.

The Regulus series began in July of this year and will end in October, 1943, when the moon will pass in front of the Lion's heart for the 17th consecutive time—once in every revolution it makes around the earth during that period. Except for one of these occultations, of short duration, visible in the Middle West on May 12th, the others are, unfortunately, practically unobservable in the United States.

However, there will be a few fairly close conjunctions of Regulus and the moon, the most notable on February 19th, just prior to the partial lunar eclipse. During the daylight occultation of Venus on July 6th, Regulus will be less than one degree away from the planet and will just miss being occulted, as we see it. I shall give further details of these events at the proper time.

The Aldebaran series began in August, 1940, and will end in December, 1943. There will be 43 occultations in 40 months, compared with Regulus' 17 in 16 months. But just as with Regulus, comparatively few of the Aldebaran series have been or may be seen in this country. They happen either in daylight or too early in the morning for the average amateur or have been hidden by cloudy weather. The next to occur, on January 16th, will be visible in all parts of the United States during the first half of the night, commencing at sunset on the Pacific Coast.

The right ascension of Regulus is $10^h\ 5^m$, and it is about one half a degree *north* of the ecliptic, in the region which the sun occupies late in August as it travels southward to the autumnal equinox. Although Aldebaran, at R.A. $4^h\ 33^m$, has a more northerly declination than Regulus, it is about 5½ degrees *south* of the ecliptic, near that part which the sun traverses in late May, when it is nearly as far north as it can go. Thus, it might seem strange that the Regulus series is so short compared to that of Aldebaran, although the former star is so near the ecliptic. The explanation lies in the fact that the moon does not travel along the sun's path, but along a path of its own which is inclined 5° 9′ to the ecliptic, crossing it only at two points or *nodes.*

The conditions which produce these two occultation series furnish an excellent example of the regression of the moon's nodes (westward) along the ecliptic, which phenomenon I explained somewhat in detail in the July, 1941, issue of The SKY. The dotted lines in Figures 1 and 2 show how the moon's path crosses the ecliptic at points which are successively farther and farther west, until in 18.6 years the nodes have regressed completely around the ecliptic. Of course, the path of the moon itself is toward the east, as indicated by the arrows on the dotted lines.

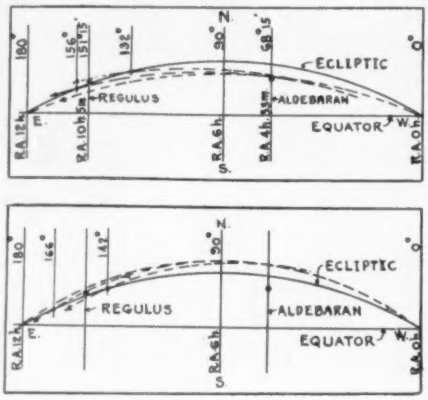


Fig. 1 (above). Current positions of moon's orbit. Fig. 2 (below). Nine years earlier.

In Figure 1, the dotted line extending fully from **W** to **E** represents the path of the moon on April 27, 1941, when the ascending node, where the moon crosses the ecliptic from south to north, was at the autumnal equinox, **E** on the diagram. By the middle of July, 1942, the node had regressed to the position marked 156°, bringing the moon's path slightly south of Regulus, but close enough for observers in the most southerly part of the earth to see the star occulted. At every revolution of the moon, the westward motion of the node brings the path of the moon farther north and occultations of Regulus are visible successively in the south temperate zone, the tropics, and the north temperate zone. Finally, the last is seen from the most northerly latitudes when the node reaches the position marked 132°, in October, 1943.

Meanwhile, the descending node, which is at the vernal equinox, **W** in Figure 1, is also moving westward and in slightly more than nine years arrives at the autumnal equinox as shown in Figure 2. Then a new series of occultations of Regulus will begin, but this time, as shown in the diagram, the order will be reversed, the moon's path moving southward as the descending node moves westward. The occultations will begin when the node is at 166° and continue until it reaches 142°. The first of the series will be seen by observers in high northern latitudes instead of in southern latitudes, as in Figure 1. The previous series of occultations of Regulus of this type took place in 1932-1933.

Comparison of Figures 1 and 2 in Aldebaran's case shows that this star can only be occulted when the ascending node is near the autumnal equinox and Regulus, Figure 1, and not under the conditions of Figure 2. Therefore, series of Aldebaran occultations are 18 years apart, instead of only nine years, as in the case of Regulus. The present Aldebaran series began in August, 1940, when the ascending node was at 193° (not shown on the diagrams), 13° east of the autumnal equinox. At that time, the moon's path was still north of the star, so the first occultations were only visible in high northern latitudes. By February, 1942, the path had moved sufficiently south (node at 164°) so occultations could be seen from just below our equator, but after that the motion changed to northward again. Thus, the end of the series will also be observed from high northern latitudes, when the node reaches 129°, in December next year. Aldebaran is too far south of the ecliptic for its occultations ever to be observed south of the tropical zone.

To avoid confusion of lines on the diagram, I have not shown the moon's path when close to Aldebaran. Owing to precession and varying distance of the moon, the actual dates of occultations in successive series do not agree exactly with the 18.6-year interval of the regression of the nodes.

THE GEMINID METEORS

The Geminids will be at maximum on December 12th and 13th. In recent years, this shower has proved to be the most brilliant of the better-known displays. Last year we counted 20 Geminids in the half hour just before midnight of the 12th.

PHASES OF THE MOON

New moon	December 7,	9:59 p.m.
First quarter	December 14,	1:47 p.m.
Full moon	December 22,	11:03 a.m.
Last quarter	December 30,	2:37 p.m.

MINIMA OF ALGOL

December 6, 5:38 a.m.; 9, 2:27 a.m.; 11, 11:16 p.m.; 14, 8:05 p.m.; 17, 4:55 p.m.; 26, 7:22 a.m.; 29, 4:11 a.m.

Answers to DO YOU KNOW?

(Questions on page 11)

1, light-gathering, magnifying, resolving; 2, eyepieces, objective, eyepiece; 3, lens, mirror, focal length; 4, Newtonian, Cassegrainian, Gregorian, Schmidt, focal length; 5, diameter, objective, focal length, aperture, focal ratios, reflectors, eight, 3.3; 6, square, aperture; 7, eyepiece, telescope, camera, focal plane, curved, bent; 8, definition, degree, spherical, parabolic.

OCCULTATIONS—DECEMBER, 1942

Local station, lat. 40° 48′.6, long. $4^h\ 55.8^m$ west.

Date		Mag.	Name	Immersion	P.*	Emersion	P.*
Dec.	3	2.9	γ Virginis	6:17.8 a.m.†	120°	7:36.4 a.m.†	295°
	15	5.9	14 Ceti	4:12.4 p.m.	59°	5:26.6 p.m.	251°
	20	6.0	179 B Tauri	4:12.8 a.m.	157°	4:31.8 a.m.	191°
	25	5.2	o^1 Cancri	8:59.1 p.m.	125°	9:50.7 p.m.	246°
	25	5.6	o^2 Cancri	9:06.5 p.m.	59°	9:56.3 p.m.	312°

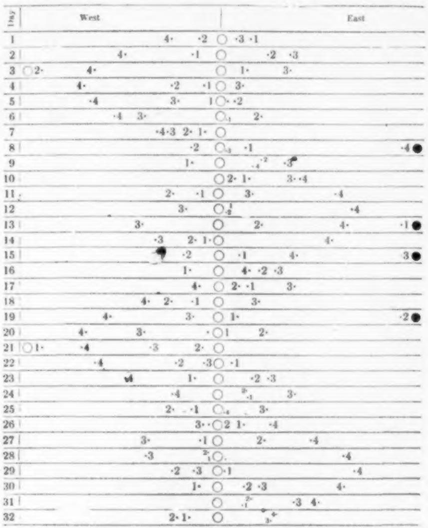
* P is the position angle of the point of contact on the moon's disk measured eastward from the north point
† Time given is for the mean of the two components.

★ ★

THE list of double stars in the adjoining columns is the fourth in a series which will cover the entire sky, furnishing amateurs with complete observing data on bright, resolvable binaries. See the "Observer's Page" in the issues of June and July, 1942, for an article on the visual observation of double stars. Previous lists appeared in June, August, and October. The next will be in February, for 4h to 8h.

JUPITER'S SATELLITES

Jupiter's four bright moons have the positions shown below at 2:30 a.m., E. W. T. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, and eclipses and occultations by black disks at the right. From the American Ephemeris.



LIST OF DOUBLE STARS—R. A. 0h to 4h

	Star	R. A. h	R. A. m	Dec. °	Dec. ′	Photometric mag. A+B	A	B	Aitken mag.	Spectra A	Spectra B	Sep. ″	P.A. °
Andromeda	π	0	34.2	+33	27	4.44	......	......	4.5—9.0	B3	....	36.1	174
	γ	2	0.8	+42	6	(2.2)	2.28	5.08	3.0—5.0	K0	A0	10.0	62
	59	2	7.8	+38	48	(5.6)	6.05	6.71	6.7—7.2	A0	A2	16.6	35
Aries	γ	1	50.8	+19	3	(4.0)	4.75	4.83	4.2—4.4	A0p	A0p	8.3	0
	λ	1	55.1	+23	21	4.83	......	......	4.9—7.7	A5	....	37.4	46
	ε	2	56.3	+21	9	4.64	5.25	5.55	5.7—6.0	A2	....	1.5	204
Camelopardalis	2H	3	25.0	+59	46	4.42	......	(9.0)	4.7—9.0	B9p	....	2.4	160
	9H	3	52.9	+60	58	5.22	......	......	5.0—8.2	K0	K4	1.9	47
Cassiopeia	21	0	42.3	+74	43	Var. (5.7 to 6.1)			5.7—9.7	A2	....	(36.5)	160
	η	0	46.1	+57	33	3.64	......	......	4.0—7.6	F8	....	(9.0)	(290)
	ι	2	24.9	+67	11	4.59	(4.6)	(7.1)	4.2—7.1	A5p	F5	2.4	251
Cepheus	47	2	59.4	+79	13	5.66	......	(9.0)	6.3—9.5	Ma	....	4.8	231
Cetus	12	0	27.5	— 4	14	6.04	......	......	6.2—11.0	K5	....	10.0	190
	ν	2	33.2	+ 5	23	5.02	......	(9.6)	5.0—9.6	G5	....	7.8	83
	γ	2	40.7	+ 3	2	3.58	......	(6.8)	3.0—6.8	A2	F4	3.1	293
Eridanus	θ	2	56.4	—40	30	(3.0)	3.42	4.42	3.4—4.4	A2	A2	(8.2)	(87)
	f	3	46.8	—37	46	4.86	......	......	4.9—5.4	B8	A0	(8.0)	209
	32	3	51.8	— 3	6	(4.6)	4.95	6.33	4.0—6.0	G5	A2	7.0	347
Fornax	ω	2	31.7	—28	27	4.95	......	......	5.0—8.0	B9	....	11.0	245
Perseus	θ	2	40.8	+49	1	4.22	......	......	4.2—10.0	F8	M3	18.2	302
	η	2	47.0	+55	41	3.93	......	......	4.0—8.5	K0	....	28.0	301
	ε	3	54.5	+39	52	2.96	......	......	3.1—8.3	B1	....	9.0	9
Pisces	35	0	12.4	+ 8	33	(5.7)	5.87	(8.1)	6.2—7.8	F0	....	11.8	148
	ψ	1	3.0	+21	12	(5.0)	5.55	5.82	4.9—5.0	A2	A0	30.0	160
	ζ	1	11.1	+ 7	19	(5.2)	5.57	6.49	4.2—5.3	A5	F8	23.6	63
	α	1	59.5	+ 2	31	4.33	......	5.23	4.0—5.0	A2p	A3n	2.2	302
Sculptor	ε	1	43.3	—25	18	5.39	......	(9.4)	6.0—10.0	F0	....	4.7	48
Triangulum	ι	2	9.5	+30	4	5.43	......	6.99	5.0—6.4	G0	F2	(3.9)	(72)
Ursa Minor	α	1	48.8	+89	2	2.12	......	......	2.0—9.0	F8	....	18.3	218

The columns are: star designation; right ascension, declination (1950); photometric magnitudes; "Aitken" visual magnitudes; spectral classes; separation; position angle.

A and *B* are the brighter (primary) star and fainter star, respectively. Where available, the photometric magnitudes are given to two places; magnitudes in parentheses are estimated or uncertain. "Aitken" magnitudes are from visual observations and often differ greatly from the photometric figures, therefore the former are useful chiefly to indicate the relative magnitude difference between the components.

The data for this table is compiled from the Boss *General Catalogue;* Aitken's *Double Star Catalogue;* and Innes' *Southern Double Stars.*

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PLANETARIUM NOTES

Sky and Telescope is official bulletin of the Hayden Planetarium in New York City and of the Buhl Planetarium in Pittsburgh, Pa.

★ **THE BUHL PLANETARIUM** presents in *December,* THE STAR OF BETHLEHEM.

The story of the Wise Men and the star that led them to the town of Bethlehem is one we all know well. Yet we do not know what star that might have been, or even if it really was a star. That is why this historical mystery is so intriguing, since in Biblical times the word "star" was loosely applied to many types of heavenly bodies. The great astronomer, Kepler, student of the planets' motions, suggested one of the most plausible and dramatic possibilities for this first Christmas star—a rare configuration of three brilliant planets which his computations showed occurred about the time of the birth of Christ. This is just one of several possibilities which in December are recreated in the Buhl Planetarium's sky for visitors to choose from. Under the same stars that shone down upon Palestine 2,000 years ago, we relive the experiences of the shepherds who watched their flocks by night, of the Magi who journeyed to worship their new King.

★ **THE HAYDEN PLANETARIUM** presents in *January,* STARS OF A WINTER NIGHT.

The story of the stars is an old one but ever new. In "Stars of a Winter Night" Hayden Planetarium audiences will see the ancient constellation figures and hear retold again the stories of these fantastic people and animals in the stars. The modern view of the stars will be presented by beautiful photographs from our leading astronomical observatories.

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